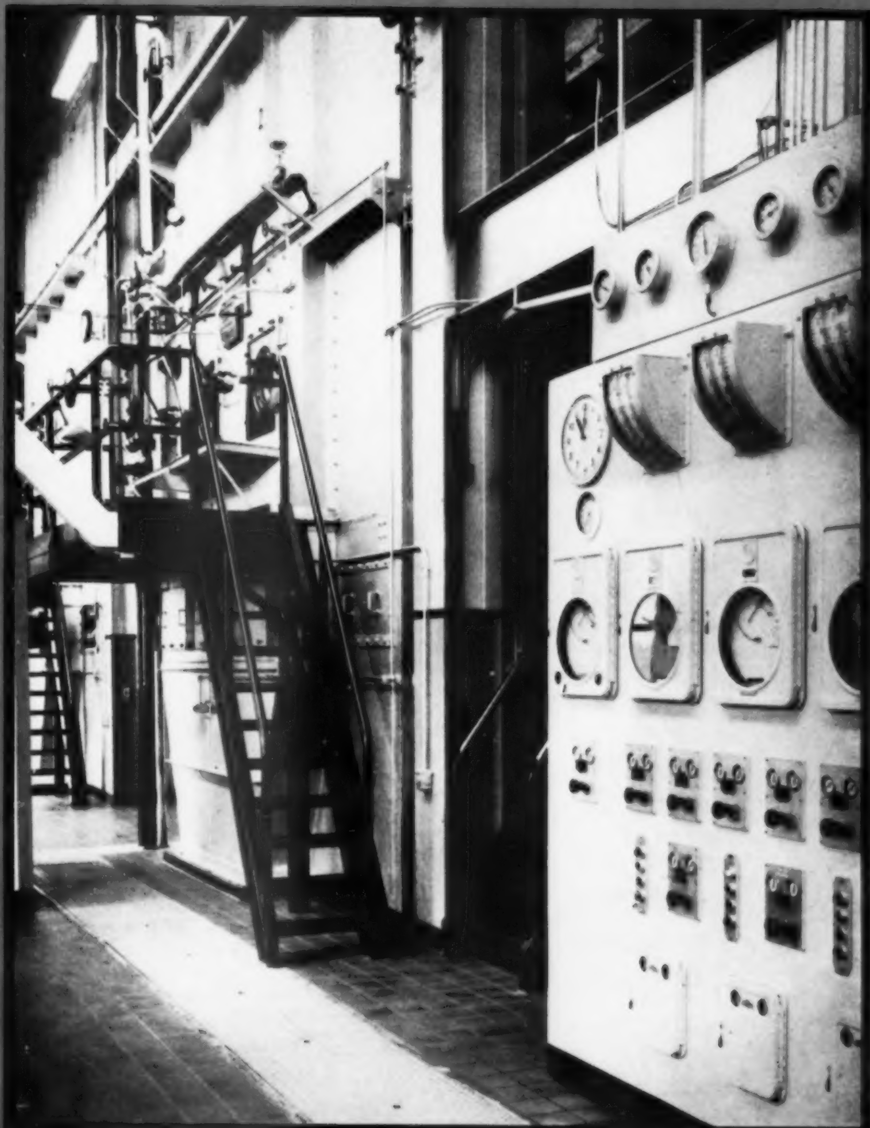
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

April 1952



One of three boilers in a Massachusetts automobile plant

First American Power Conference

Features of Etiwanda Steam Station

Interest in Electrostatic Precipitation

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Vol. 23 **No. 10**

April 1952

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COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc.

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Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING-SUPERHEATER INC.

Joseph V. Santry, President; Charles McDonough, Vice-President; H. H. Berry, Secretary and Treasurer
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up and to consulting engineers in this field. To others the subscription rate, including postage, is $3 in the United States, $3.50 in Canada and Latin America and $4 in other countries. Single copies: 30 cents.

Publication Office, Easton, Pa. Issued the middle of the month of publication.

Acceptance under Section 34.64, P. L. & R., authorized by United States Post Office.

Printed in U. S. A.

COMBUSTION

Editorials

Whither Are We Headed?

Addressing the recent American Power Conference in Chicago, C. H. Lang, vice-president of General Electric Company, reiterated a prediction he had made two years ago that the annual electric utility output in the United States would reach a trillion kilowatt-hours by 1970. Last year it was about 370 billion, of which over three-fourths was fuel-generated. This prediction would appear to be in line with the rate of increase that has prevailed, with slight variation, for several decades; that is, nearly doubling every ten years. In fact, population growth, with ever-increasing per capita use of electricity, both industrially and domestically, would probably sustain such a rate increase, not to mention the various defense projects that will require vast quantities of power for some time to come—all of which figure in the present unprecedented construction program of the electric utility industry.

One effect of the rapidly increasing demand for electric energy is that it makes for larger system loads, which, in turn, justify the installation of larger and larger steam-generating units and turbine-generators. As a consequence, there are now building single boiler-turbine-generator units of 200,000 kilowatts capacity and designers are reported to be considering units of 300,000 kilowatts. Obviously, larger units mean both lesser initial investment per kilowatt and reduced labor cost per unit of output.

From the standpoint of fuel use, if the average fuel consumption per net kilowatt-hour output that existed twenty years ago had been in effect last year, the total fuel consumption in terms of coal equivalent would have been about 55 million tons greater—a saving that went a long way toward offsetting increased fuel prices.

The improvement, of course, has been attributable to several factors, including more efficient equipment, better station design with greater refinements, more economical loading, and, particularly, to improved cycle efficiency As the number of new stations going into service increases, especially those employing high temperatures with reheat, the average station heat rate will approach closer to the goal set by the most efficient plants. Even now much thought is being given to the employment of two reheat stages in order to gain another two or three per cent in station performance.

However, continued improvement in average station heat rates will be in smaller increments until, perhaps, some radical basic change in power generation takes place.

It is much easier to predict energy use by 1970, as Mr. Lang has done, than it would be to predict station performance by that time.

A New Thermodynamic Energy Concept

Our contemporaries, *Power* and *Chemical Engineering*, have published a stimulating, and what promises to be, a provocative, article based on a forthcoming McGraw-Hill book by Neil P. Bailey, Russell Sage professor of mechanical engineering at Rensselaer Polytechnic Institute. Briefly stated, this new concept proposes to reduce the four quantities relating to energy (namely, potential energy, kinetic energy, internal energy and flow work) to three quantities (internal energy, kinetic energy and "transmitted energy"). In this way it is aimed to account for some of the discrepancies that have appeared at times between calculated and test results.

Quite naturally, many designers in the field of steam power will be interested and concerned, especially as to such effect as the new hypothesis may have on the steam tables and the computation of boiler and turbine efficiencies. If it should become widely accepted, practicing engineers will be confronted with an intellectual chore in adjusting their thinking to the new energy concept. On the other hand, it may make the study of thermodynamics easier for future generations of engineers.

It is suggested that, before "going overboard" for Professor Bailey's theory, it would be well for one to give serious consideration to a series of lectures on classical thermodynamic theory by Dr. Myron Tribus of the University of California at Los Angeles, which were delivered some time ago at Purdue University and which have recently been published by the latter's Experiment Station under the title "Thermodynamics in an Engineering Curriculum."

All technology rests on a base of pure and applied science. Thermodynamics, historically, has varied from the intensely practical experimental work of Rumford, Joule and Rankine to the abstruse mathematical theory developed by Carnot, Clausius, Lord Kelvin, Maxwell and Josiah W. Gibbs. There are some who anticipate that Professor Bailey's approach to the subject will eventually lead to his name being placed among these outstanding thermodynamicists. But no matter what ultimate acceptance the new energy concept may be accorded, the understanding of thermodynamics is certain to be strengthened by the spirited and critical debate that is likely to ensue.

First American Power Conference

ATTENDANCE at the American Power Conference at the Sherman Hotel, Chicago, March 26–28, exceeded that of any of the past Midwest Power Conferences which it replaced, the total registration being more than 2500. Concurrent with the conference the NAPE held its annual power show.

Besides an excellent and well-balanced technical program, there were a number of addresses on economic problems and matters of public concern.

At the opening session **George M. Gadsby,** president of the Utah Power and Light Company and of the Edison Electric Institute, had as his topic "The Great Accomplishment of a Free People." He attributed the record additions to central station capacity during 1951 to the creative genius of a free people who are able to function in spite of, and not because of, government planning. The importance of the electric power industry, he pointed out, may be realized more fully when it is understood that for an increase of 20 per cent in industrial output there is required an expansion of 40 per cent in central station capacity.

"There is need," Mr. Gadsby added, "for more incentive to the electric power industry in terms of higher returns on investment." It was also his conviction that the greatness of this country can best be maintained by supporting government in the fields for which it is intended and by allowing private enterprise to assume the proprietary functions for which it is best fitted.

Another speech along somewhat similar lines was given by **P. H. McCance,** president of the Association of Edison Illuminating Companies, and of the Duquesne Light Company, who attributed the unparalleled growth of the electric industry to (1) inventive genius; (2) the skill of equipment manufacturers; (3) ability of utility companies to provide increased amounts of energy at lower consumption cost; and (4) to the willingness of the public to make the necessary investments for the construction of generating and distribution facilities.

The speaker voiced the opinion that a large supply of electric energy can be expected in the future provided we recognize and are prepared to deal with potential dangers that can affect the path of anticipated growth.

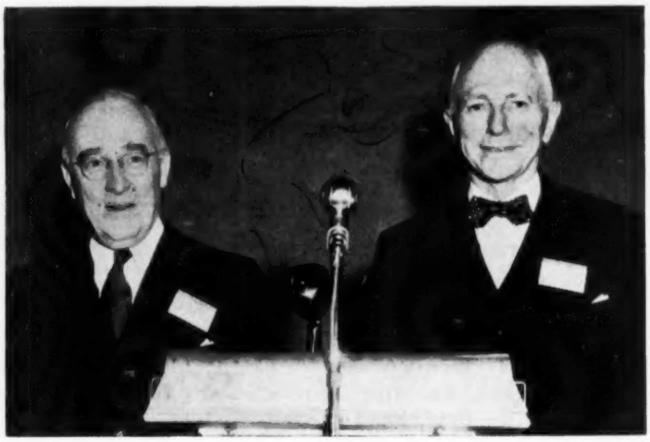
He cautioned against attempts to socialize the utility industry, which, if successful, would spread to other industries as it has done in England. He added that mere size is not the measure of success unless such growth is accompanied by sound development of business and operating results such as will assure an adequate return on the invested capital.

Economic Facts Need Be Told

At the session on "Public Attitude and What Can Be Done About It" a stirring talk was given by **Edwin Vennard,** vice president of the Middle West Service Company, who contended that the only real defense against the socialist trend in the United States is better public understanding of a few simple economic facts. "There are only two kinds of government," he said, "the kind where the government runs the people and the kind where the people run the government." Although history shows very few times when people have been free, that of the American Republic is the best example of man's ability to improve himself when government leaves him alone. The Russians, Italians, Germans and recently the English, all in turn, Mr. Vennard pointed out, were dominated by a highly centralized government that controlled the economic life of those nations, as a result of which the common man lost much of his individual freedom.

Widely misunderstood economic facts cited by Mr. Vennard are as follows:

1. Many people are of the opinion that business profit is about 25 per cent, while believing that 10 per cent is a fair figure. They don't know that for the last 20 years in America the actual average profit of manufacturing concerns has been from 4 to 6 cents on the dollar sales.
2. The record of all manufacturing industries in the United States for the last 20 years shows that employees get 80 cents for every 20 cents the owner receives.
3. It is not generally realized that machines now do 94 per cent of all the work that is done in the United States and that machines make jobs in the long run. Also, that the only way workers can get more real income is to produce more with the help of more and better machines.
4. Few people know that 65 per cent of all national income is paid out in wages and salaries, and that after



P. H. McCance and Alex D. Bailey

income taxes about 90 per cent of the remainder is in the hands of people who have incomes of less than $100 per week.

Mr. Vennard concluded that the drift toward socialism will continue until the businessmen in the United States take care of their responsibility to communicate simple economic facts to their employees.

Vision in Power

Philip Sporn, president of the American Gas and Electric Service Corp., delivered an inspiring address on the rôle of foresight in the future development of the public utility industry. Noting that the word vision has the antithetical meanings of being able to see things

directly and also of being capable of seeing invisible things in the future, Mr. Sporn succeeded in showing how important vision, in the latter sense, is for meeting the future responsibilities of the power industry.

While almost any engineer is capable of making economic studies and evaluations, it takes an engineer of vision to know what to do with them. Vision has the characteristic of being swift and transient, so that it is often necessary for the engineer to perceive a clear basis for judgment in an instant. New devices necessary to realize envisioned technological developments must also come into being in a somewhat similar manner.

Philip Sporn and Walker Cisler

Vision is impossible without knowledge of the aims and objectives of persons in the community. There must be an awareness of changes in people, in the political area, and in the changing nature of thought. Noting that maximum power development requires large capital investment, Mr. Sporn emphasized the need for long-range planning of a somewhat visionary nature in order to forestall as far as possible obsolescence. He saw no reason why, with technology still progressing, further improvements in central station efficiency and transmission line potential should not be made. In concluding, Mr. Sporn threw out the challenge that it would be a sad day when the power industry loses vision.

The Joppa Station for Atomic Energy Power

R. E. Moody, executive vice president of the Union Electric Company of Missouri and vice president of Electric Energy Inc., told of the formation of the latter organization to build the Joppa steam-electric power plant to supply power to the Atomic Energy Commission's new project at the site of the old Kentucky Ordnance Plant 16 miles west of Paducah. Incidentally, this power plant, with an initial capacity of 652,000 kw, will be the largest steam-electric station ever built in a single construction operation and is expected to be producing power by the end of 1952.

The project was conceived and the site selected by AEC less than two years ago. To supply the required power, Electric Energy Inc. was formed in December 1950 jointly by the Union Electric Company of Missouri, the Illinois Power Company, the Central Illinois Public Service Company, Kentucky Utilities Inc. and Middle South Utilities Inc., these companies subscribing to 40, 20, 20, 10 and 10 per cent, respectively, of the $3^1/_2$ million capital stock. One hundred million-dollar first mortgage 3-per cent bonds were subscribed by the Metropolitan and the Prudential Life Insurance Companies, this figure covering the estimated cost of the power plant. The participating companies are building the necessary transmission lines at their own expense. These will include a 230,000-volt line, with wood towers, from East St. Louis to Joppa and four 4700-ft spans across the Ohio River from the power station to the atomic energy plant.

Ebasco Services Inc. was engaged to design and construct the power plant which will contain initially four 163,000-kw turbine-generators operating at 1800 psig, 1050 F and 1000 F reheat. Each will be served by a single boiler, and the unit system is adhered to throughout, as this duplication in design and layout adds to both economy and speed of construction. To date 50 days have been lost because of jurisdictional strikes.

Coal will be delivered by either barge or rail and at full load it is expected to consume between 7000 and 8000 tons daily.

Oak Creek Station

Certain design features of the new Oak Creek Station of the Wisconsin Electric Power Company were described by **O. J. Stallkamp,** assistant chief design engineer of that company. This station, located on Lake Michigan about ten miles south of Milwaukee, is now in the early construction stage. Designed for four 120,000-kw units, the first of which is scheduled for operation early in 1953, its principal features are a single boiler per turbine, radiant and convection superheaters in series, radiant reheaters, bin-and-feeder pulverized coal system, controlled-circulation boilers, cross-compound turbines, vertical pumps, pressurized circulating water tunnel and centralized control. The steam conditions will be 1750 psig design pressure (1575 psig at the turbine throttle) 1000/1000 F steam temperature and 0.5 in. back pressure.

The controlled-circulation boiler, of Combustion Engineering-Superheater design, will be provided with three 3500-gpm single-suction constant-speed circulating pumps, two being sufficient for full load and the third a spare. The primary radiant superheater will be located on the back wall of the furnace and be connected in series with the primary convection superheater, whereas the radiant reheaters will be on the side walls. With a furnace volume of approximately 120,000 cu ft the heat release at maximum load will be about 10,000 Btu per cu ft per hr. This relatively low heat release is expected to avoid serious slagging.

The cross-compound type of turbine-generator, supplied by Allis Chalmers, consists of a 3600-rpm, 80,000-kw high- and intermediate-pressure machine and an 1800-rpm, 40,000-kw double-flow low-pressure machine. Tied together electrically, the generators will always operate as a unit. Although 3600 rpm throughout would have meant smaller parts, smaller clearances and lesser cost than 1800 rpm for the low pressure turbine, the blading for the exhaust end could not be made long enough to pass efficiently the tremendous volume of steam expanded to 0.5 in. back pressure. To obtain a flow area at the exhaust end equal to that of an 1800-rpm machine, a 3600-rpm turbine would have required six exhaust wheels and multiple condensers instead of the two ex-

haust wheels and a single condenser. Therefore, by cross-compounding a 3600-rpm high-pressure turbine with an 1800-rpm low-pressure turbine the advantages of each were had, as well as the most economical balance of investment and operating costs for the expected load conditions.

Turbine Controls

Charles F. Wilson of Allis-Chalmers Mfg. Company presented a paper dealing with basic controls of central station steam turbines. He divided these controls into four general classifications: namely, those for starting and stopping the machine; those for governing and maintaining regulation; those for turbine auxiliary equipment; and those for safety and automatic protection of the machine.

Some of these are manually operated and some are automatic. Generally speaking, the turbine is started, brought up to speed and synchronized by manual controls; and after it is on the line the automatic controls take over.

Most of the controls are hydraulically operated, using turbine oil at 150 psig as the operating medium. When the turbine is up to speed centrifugal pumps mounted on the turbine shaft pump all the oil used by the turbine for control and lubrication. In some cases two shaft-driven pumps are used—one pumping oil at 150 psig for use in the control system and the other pumping oil at 40 psig for use in the generator control system and for lubricating the bearings. The two systems are connected by a pressure-regulating valve which automatically maintains a predetermined oil pressure on the downstream side. The lower pressure oil passes through coolers after which part is diverted to supply the generator hydrogen seal system and the balance passes through another pressure-regulating valve adjusted to maintain about 10 psig in the bearing lubrication system. Auxiliary oil pumps with automatic starting devices are provided to back up the main pumps, for if the flow of oil should cease when the turbine is at speed, it could not be stopped quickly enough to prevent wiping the bearings.

On larger machines a high-pressure lift pump is provided to float the turbine and generator shafts on a film of oil when the speed during starting and stopping is too low to build up a hydrodynamic oil film in the bearings.

The speed governor must be designed to operate quickly so that it can properly control the turbine and prevent overspeeding in the event of sudden loss of load. The relatively small governor force is amplified by a servo-motor to move the steam valve.

The stop valve is very important because it is often the only shut-off between the boiler and the turbine inlet valve. Where overspeeding might occur because of some interference with normal operation of the inlet valve, the stop valve is designed with an automatic control to shut off all steam to the turbine. When the main stop valve has been tripped it is desirable to automatically close the governor-controlled inlet valves in case they have not been closed by other normal means.

Mr. Wilson recommended that the trip test be performed at least once a day during the initial period of operation of the machine in order that abnormal operating conditions, such as valve-stem deposits, can be brought to the operator's attention before they become excessive.

Thermal Design and Efficiency of Steam Turbines

"Thermal Efficiency and Design of High-Temperature Reheat Turbine-Generator Units" was the title of a paper by **J. R. Carlson** of Westinghouse Electric Corporation. In this the author showed that the heat consumption of turbine-generators in Btu per kwhr is a better means of evaluating the economics of more advanced steam conditions and various turbine ratings than the straight condensing steam rates formerly employed. He submitted a table showing recommended operating conditions up to 2400 psig and 1100 F and the corresponding heat rates for capabilities up to 200,000 kw.

The first unit to be placed in service using a reheat steam temperature of 1000 F and initial conditions of 1450 psig, 1000 F was the 81,250-kw three-cylinder unit at the Edgar Station of the Boston Edison Company. Since this was undertaken in 1946, orders for sixty turbine-generators totaling more than seven million kilowatts capability have been received by Mr. Carlson's company.

For ratings from 62,500 to 125,000 kw capability the two-casing tandem-compound reheat turbine appears to have the greatest acceptance. In this design, the high-pressure and intermediate-pressure elements are contained within the high-pressure casing with expansion continued through a double-flow low-pressure element.

The largest single-shaft 3600-rpm now in service is at the Sewaren Station of the Public Service Electric & Gas Company. This is rated at 125,000 kw. A unit of 185,000 kw capability at 2350 psig, 1100 F initial and 1050 F reheat is now on order for this company.

Another turbine of noteworthy rating is the 200,000-kw single-shaft machine being built for the Cromby Station of the Philadelphia Electric Company. The steam conditions will be 1800 psig, 1000/1000 F and 1-in. Hg abs.

Although the Preferred Standards were extended two years ago to include 100,000 kw units, with or without reheat, the percentage of orders received for standard units since then, on a kilowatt basis, has declined from 79 per cent of those shipped in 1951 to 74 per cent of those expected to be shipped in 1952.

There are believed to be several reasons for this. First, that the standards should be extended to cover larger ratings in line with the trend; and second, that steam conditions on the smaller sizes have not been kept abreast of current economic conditions.

Further improvements in thermal efficiency can be obtained by going to higher pressures and temperatures, such as 2800 psig, 1150 F; but the incremental reduction in heat consumption becomes smaller for each increased step in steam conditions. However, by adopting a second stage of reheat, a net reduction in heat consumption of about 2 per cent becomes possible.

Large Utility Boilers

At the session on "Modern Steam Generators," two papers were presented, one by **H. B. Wallace** of Foster Wheeler Corporation and the other by **W. H. Rowand** of Babcock & Wilcox Company.

Mr. Wallace listed the general trends in steam generation as:

1. Designing to accommodate the use of worse and worse fuels with no penalties in economy.

2. Improvements in cycle efficiency to offset increasing fuel, labor, material and construction costs, through employment of higher steam temperatures and pressures; reheating and consideration of multiple stages of reheating; and the possibility of reducing tail-end temperatures.

3. Achievement of purer steam through application of dual circulation and improved water conditioning.

4. Natural circulation versus forced circulation.

5. Pressurized combustion.

6. Combustion of completely versus partially pulverized coal.

7. Development of quick-starting techniques.

After discussing each of these points he added that "the fashions of steam generator design consist of the realignment of the unit as a result of standardization of details of entire areas to permit savings in engineering costs through repetitive practices, those resulting from operating experiences, and those due to fabrication and field construction improvements."

Mr.Rowand discussed at some length the influence of various fuels on boiler design and observed that although some utility plants are favored with a reliable and abundant local source of fuel such as to justify reliance on a single fuel, in the majority of cases it is advantageous to plan for use of more than one fuel to take advantage of price fluctuations or assure continuity of operation.

He added that with steam-generating units of very large size it becomes advisable to employ a division wall in the furnace, since the required heat-absorbing surface can be obtained with less total furnace width and less total furnace volume than in a single furnace. Also, present-day utility boilers cannot be satisfactorily compared on the basis of steam flow alone because of the large proportion of heat absorption credited to the superheater and reheater. Steam flow is important, however, in fixing the circulation characteristic, in determining the load imposed on the steam purifying drum internals and in setting safety valve capacities.

Boilers, he said, are now being designed for heat inputs of 1.9 billion Btu per hr to serve turbines of more than 200,000 kw output, and it is likely that utilities will require still larger units in the future as electrical systems grow bigger and larger blocks of power can be conveniently handled.

Boiler Tube Corrosion

In a paper on "Boiler Tube Corrosion in British Power Stations," **E.W.F. Gillham** and **R. L. Rees** of the British Electricity Authority reviewed the results of a survey of 94 power stations in which about a third showed boiler tube corrosion. In these, operating pressures ranged from 350 to 1450 psig.

While in most cases the corrosion had developed since the war, it had been observed in 1944 in both Battersea and Fulham Stations where the boilers are fed with good quality condensate and evaporated town water of relatively high carbonate content to which soda ash is added.

Although no corrosion was observed in the tubes of the eight forced-circulation central station boilers at present operating in Britain, boiler design did not appear to be a factor in the corrosion. It was observed in zones of relatively low heat transfer and to occur more commonly in boilers operating at pressures under 400 psi. However, when occurring in zones of high heat transfer, it appeared to be promoted by high concentrations of dissolved oxygen in the feedwater, by low alkalinities and by high neutral salt concentrations. When occurring in radiant sections, the corrosion appeared to produce scabs of magnetic iron oxide having a laminar structure.

The authors reported that the continuous addition of alkaline substances such as caustic soda, tri-sodium phosphate and mixtures of caustic soda with other phosphates to the feedwater appeared beneficial.

Sodium sulfate is used extensively in these stations as a scavenger, but where the dissolved oxygen is high (over 0.1 ml per liter) the sulfate does not appear to provide the required protection. The best protection appears to lie in maintenance of oxygen concentrations below 0.03 ml per liter and judicious use of sodium sulfate. No other scavengers are being employed in British power stations.

In a considerable number of the stations deposits of metallic copper and copper oxide were observed. The copper was believed to have originated in evaporator tubes and the bronze impellers of the feed pumps. It was more evident in those stations having high feedwater temperature. There was no evidence, however, that the copper deposits were responsible for the tube corrosion, and in many cases there was corrosion and no copper deposits.

While there were only a few instances of caustic embrittlement, it did occur at Battersea B with 1420 psig pressure under thin corrosion scabs. Here it was confined to the lowest row of sectional-header tubes and neither pH-sulfate ratio control of the boiler water alkalinity nor continuous sulfite injection has been successful in arresting the condition.

Two other cases of embrittlement were noted in boilers operating at 600–700 psig and occurred beneath steep-sided pits filled with laminar scabs of iron oxide. In one case the intergranular cracking occurred in furnace wall tubes of a multi-drum boiler in which low alkalinity had been maintained.

Steam Condensers

With reference to design considerations of condensers, **G. H. Putnam** of Ingersoll Rand Company urged that customers call for guarantees at or near the expected average operating conditions of load and water temperature rather than at maximum load and maximum water temperature. Moreover, it is preferable that the water temperature be taken as the mean average summer temperature.

The true measure of condenser performance, he pointed out, is the overall coefficient, or rate, of heat transfer from the steam through the tube walls to the circulating water, as expressed in Btu per sq ft per hr per deg F mean temperature difference. But since it is difficult to determine accurately the actual overall coefficient for a condenser in operation, it is difficult to compare actual performance with guaranteed performance. It is hard to get accurate readings on the rate of net steam flow to the condenser, its total heat content per pound, the rate of water flow through the condenser, or an accurate measurement of the absolute pressure at the condenser inlet,

since this may vary around the periphery of the steam inlet.

While condenser manufacturers cannot do anything to prevent accumulations of silt, slime and scale on the inner surfaces of tubes, which result from local conditions, they can so design as to facilitate cleaning operations. Water boxes should have divided water circuits so that half the water space may be shut down for cleaning while the other half carries the load at reduced vacuum. In this connection, Mr. Putnam described the reverse-flow valve to be installed between the circulating pump and the condenser to permit backwashing of tubes, tube sheets and water boxes.

He expressed the opinion that at least 90 per cent of surface condensers in use are not performing as well as they should due to fouling of tubes, faulty operation of air-removal equipment or excess air leakage. In fact, every condenser should be equipped with an air-leakage meter.

The most critical part of a condenser the author believed to be the air-cooler section. Velocities must be maintained such as will keep the cooling surfaces free of insulating air, and multiple vapor passes must be provided to prevent hot streaks of uncondensed steam from short-circuiting to the ejector and overloading it.

Interconnection of Utility and Industrial Plants

In discussing the interconnection of industrial plants and central stations, **V. F. Estcourt** of Pacific Gas & Electric Company described the arrangement that exists between his company and three oil refineries in the San Francisco region. This involves the Avon steam plant of the Tidewater Associated Oil Company, the Martinez plant of Shell Oil Company and the Oleum plant of the Union Oil Company, all of which have now been in service from ten to eleven years.

Under the terms of the contracts the power company constructed and operates the steam-electric plants adjacent to these respective refineries, which are supplied thereby with process steam and electricity. Payments by the refineries under the contract consist of a cash demand charge plus a commodity charge partly in cash and partly in "substitute fuels" in the form of acid sludge, pitch, heavy fuel oil, asphalt, acid tar or pulverized petroleum coke. The quantity of fuel is determined by multiplying the pounds of steam and the kilowatt-hours delivered by a certain factor. Excess fuel oil may be purchased by the utility to meet the full load requirements of the generating station which is tied in with the utility system. The maximum power demand in each case is 15,000 kw and that of process steam ranges from 275,000 to 325,000 lb per hr.

The three plants are in most respects similar, except that the Avon and Martinez plants each have one 50,000-kw tandem-compound turbine-generator with automatic extraction at the exhaust of the high-pressure turbine, whereas the Oleum plant has two such units.

This arrangement provides considerable flexibility in meeting seasonal fluctuations in system demand, and station heat rate at light loads is excellent due to the fact that a straight back-pressure cycle is approximated under these conditions. Moreover, it is always possible to have power for the refineries available either from their own generators or from the transmission line.

A second case of interconnection cited by Mr. Estcourt is that of a lumber company at Eureka, California, which is adjacent to one of the steam stations of his company. Here the utility furnishes the lumber mill's steam requirements at 170 psi up to a maximum demand of 18,000 lb per hr and all of its electrical needs. Payment by the lumber company is in the form of a cash demand charge plus a quantity of hog fuel equal to a certain factor times the total steam and electricity delivered.

Water Technology

A progress report entitled "Demineralization Plant Operating Experience" was presented by **M. E. Brines** of the Midland, Mich., plant of the Dow Chemical Company. To provide additional treated boiler feedwater for two 400,000-lb per hr boilers which went into service in May 1950, an extension having a design capacity of 1500 gpm was made to an existing demineralization plant. The entire water-treatment plant is operated by one man from a central control room. A 20-ft service panel records water flow to the prefilters and cation-exchangers, cation effluent to deaerators, anion effluent, and demineralized water to each power plant. Demineralized water conductivity and pH are recorded before and after pH adjustment.

The operator can make any number of cation regenerations without leaving the control room. The regenerant tank-level controls are interlocked into the cycle and will not allow regeneration to start unless the tanks are filled to the proper level. Except for manual operation of the filling of the caustic soda regenerant tank, anion regeneration is entirely automatic, including the regenerant tank interlock.

Demineralized water quality has exceeded expectations, being superior to that obtained on a laboratory or semi-plant scale. Specific conductivity is less than one micromho, CO_2 has not been detected in finished water leaving the plant, and silica content is extremely low, so that 0.03 ppm silica has been used as the cut-off point. Runs on the cation-exchangers will average 2,250,000 gal per cycle to the sodium breakthrough point, while average anion runs are 4,000,000 gal. Cation-exchange capacity ranges between 26,000 and 30,000 grains per cu ft of resin; anion-exchanger capacity is approximately 11,000 grains per cu ft.

"Initial Operation of a 500-gpm Duplex Deionizing Plant" was the title of a paper by **T. P. Harding** of the Omaha Public Power District. This water-treating plant supplies the high makeup requirements of a 1225-psig, 910-F 265,000-lb per hr combination furfural-residue-burning boiler. Deionization was selected as the most practical treatment for reducing dissolved solids and silica present in the available water supply. The water-treatment plant is a two-bed, semi-automatic duplex unit. Raw water enters the cation units, passes through a decarbonator to a neoprene-lined concrete sump, and is then pumped through the anion-exchangers to two 60,000-gal neoprene-lined concrete storage tanks. When a cation-and-anion unit is exhausted it is automatically taken out of service at the same time that a warning is

sounded. Regeneration is initiated by an operator through push-button control, following the completion of which the unit is returned to service. Automatic control is accomplished by means of pH recorders, conductivity bridges, timers, and solenoid-operated pilot valves which in turn operate the main valves.

Under present methods of operation, water of satisfactory purity has been maintained. The average deionized effluent has a mean conductance of 3.9 micromhos or 0.9 ppm in terms of equivalent sodium hydroxide. Results of the initial period of operation with deionizing equipment have been sufficiently encouraging for the Omaha Public Power District to specify deionization to supply makeup requirements for a new reheat plant now being constructed.

A. D. Simpson of the Macon Kraft Company presented a paper entitled "Hot Lime Zeolite—A 290-F Installation" in which he described how a southern kraft mill overcame some of the difficulties resulting from lack of adequate provisions for treating boiler feedwater. The Macon plant went into production April 1948 and was the first exclusive 900-psig design, steam-generating plant in the paper industry. A total steam capacity of 650,000 lb per hr is provided by two pulverized-coal, natural-gas-fired units of 150,000 lb per hr each, one refuse fuel burner of 100,000 lb per hr and two chemical recovery units having a steam output of 125,000 lb per hr each. Operating superheater outlet conditions are 850 psig, 825 F. Power is generated by one 7500-kw turbine-generator operating at 160-psig extraction and 40-psig back pressure; and two 5000-kw extraction-condensing turbines, one extracting at 160 psig and the other at 40 psig. There is also a paper-machine drive, a 2000-hp geared-turbine operating at 160-psig back pressure.

General water supply for the mill, amounting to 18 million gallons per day, is taken from the Ocmulgee River and is clarified with alum and sodium aluminate. Originally a two-stage hot-process water softener was installed for silica reduction, alkalinity correction and hardness removal. This process utilized 40-psig exhaust steam at 278 F to facilitate silica reduction and calcium phosphate precipitation. Accordingly, the station deaerator for softening makeup and condensate was installed as a thoroughfare unit with all steam required for the hot-process softener being passed through the deaerator.

With gradual increases in paper production an increased demand was made on the water-treating plant, amounting at times to 35 per cent overload. This resulted in a somewhat depreciated feedwater quality and made it advisable, because of capacity limitations on the existing equipment, to install additional water-treating apparatus. It was decided to modify the treatment and eliminate the phosphate by supplementing the primary softener with ion-exchange units.

Four Worthington softeners containing 30-in. beds of styrene resin were installed.

At the time of the starting of the new hot-zeolite plant treating chemicals to the primary softener were changed to affect lower feedwater alkalinity which resulted in blowdown reduction. Lime replaced caustic soda in the silica-removal operation, with magnesium oxide in the first stage. Sodium aluminate assisted in coagulation and resulted in improved silica removal.

Stability of the styrene cation resin used in this installation, which is subjected to temperatures of 285 to to 290 F, cannot be determined in the short time it has been operating. However, on the basis of favorable limited experience the use of the hot-lime zeolite process is today being extended to other paper mills, replacing more costly treatment methods.

R. C. Ulmer, J. H. Whitney and **J. W. Wood,** of E. F. Drew & Co., in a paper entitled "Cause and Control of Iron Oxide Deposits in High-Pressure Boilers," provided additional information on a subject which they discussed at the Twelfth Annual Water Conference held in Pittsburgh in 1951.* The work which was continued in an experimental laboratory-type boiler and in a high-pressure bomb confirmed the earlier conclusion, namely, that magnetic iron oxide, Fe_3O_4, will form adherent deposits, whereas ferric oxide, Fe_2O_3, will not. Furthermore, by maintaining slightly oxidizing conditions in the boiler water, as in the nitrite-type treatment, fewer deposits will form, and those that do will be largely of iron oxide which remains suspended in the boiler water as Fe_2O_3.

In summary, further observations of results with nitrite-type treatment have confirmed previous work indicating that no objectionable corrosion takes place on the steel even at high nitrite concentrations. On the bases of experimental work and field results, the authors suggest the following procedure for prevention of iron oxide deposits:

1. Keep the iron pickup in the preboiler system at a minimum. Low dissolved oxygen and controlled pH are of major importance.
2. Maintain a slightly oxidizing condition in the boiler water to insure that any iron present will be as Fe_2O_3 rather than as Fe_3O_4.
4. A protective film should be maintained on the boiler metal surfaces to cut down iron pickup by the boiler water and insure a smooth surface to which deposits are less likely to adhere.

In a paper entitled "The Chemical Treatment of an Evaporator at West Springfield Station" **J. R. Haskins, Jr.,** of Western Massachusetts Electric Company described the treatment for a single-effect evaporator with a deaerating-evaporator-feed preheater installed in connection with a 40,000-kw single boiler-turbine-generator unit. This evaporator operates with filtered Connecticut River water on steam extracted from the tenth stage of the main turbine, which is at 103 psia, 485 F under rated load conditions. Under normal operating procedure steam to this evaporator is throttled to give a continuous evaporator output of about 7420 lb per hr.

Since an evaporator is fundamentally a low-pressure boiler, it is reasonable to expect that scale formation may be prevented by the use of much the same techniques as are used in low-pressure stations. Therefore, a treatment was proposed in which di-sodium phosphate, sodium hydroxide, sodium sulfite and an organic material were to be introduced into the evaporator, the total dissolved solids in the evaporator concentrate being controlled by continuous surface blow. After chemical treatment was started the evaporator was operated continuously

*See COMBUSTION, Vol. 23, p. 52, November 1951, for Conference report.

for 15 months. Upon being taken out of service and opened for inspection and maintenance, it was found to be entirely free of hard scale. The author concluded with the thought that not only had the treatment eliminated any possibility of scale formation in the evaporator, but that also tube and tube-sheet maintenance had been reduced by eliminating the thermal shock present when the usual method of thermal cracking is used to remove scale.

"Feedwater Treatment in Illinois State Institutions" was the title of a paper by **Russell W. Lane** of the State Water Survey Division of the State of Illinois. There are forty institutional power plants located at prisons, hospitals and colleges with steam generating equipment varying from 25-hp hrt boilers up to 60,000-lb per hr units. In seventeen of the institutions electric power is generated by steam, and in nine of the plants modern non-condensing steam turbines are installed. Heating, however, is the primary function, and the twenty-seven larger institutions each produce 200,000 to 3,000,000 lb of steam per day during the winter months.

Although external treatment is provided at twenty-two institutions, all receive internal treatment of one form or another. The methods of external treatments are hot lime-soda softening and sodium exchange with or without subsequent acid treatment for alkalinity reduction. Two types of coagulation internal treatment are being applied as well as the phosphate-residual type. Chemical treatment costs per million pounds of steam produced in the state plants range from $1.20 to $8.90, not including cost of coal, water, amortization and other miscellaneous factors.

Fluid Drives

Ben G. Ragland of American Blower Corp., in a paper entitled "Demand Performance—Fluid Drive in the Modern Power Plant," traced the history of the fluid drive from the early 1930's to date. A fluid drive is a simple set of rotating elements composed of bowl-shaped impeller and runner, each fitted with radial webs arranged similarly to the fibrous separations found in grapefruit halves. The impeller-and-runner unit is equipped with an outer casing which forms a chamber to confine the power-transmitting liquid in the working circuit. There is no mechanical connection between impeller and runner, the transfer of power being accomplished in a hydrokinetic fashion.

Fluid drives may be classified as of the constant-speed or the adjustable-speed type. The former is well known for its use in automotive transmissions, while the latter is most commonly applied in the steam power plant. Adjustable speed is accomplished by changing the volume of oil in the working circuit, control being by means of an element called a scoop tube which plows a rotating vortex of oil located adjacent to the working circuit. The oil pump is a constant-volume unit, and the adjustment of flow in the cycle is controlled by the position of the scoop tube whose capacity and pressure varies in relation to the inner diameter of the vortex.

For boiler feed pump operation the ideal condition is to have the pump develop only sufficient pressure to meet boiler output plus friction demands. The requirement of falling head at decreasing flow can be met by a variable speed device driving the pump. Salient features of the hydraulic coupling in its application to feedwater control include the following:

1. It has justified its use on power savings, since the required pressure only has to be held.
2. It more than meets the speed-change response set by the boiler feedwater demand.
3. It has flexbility of control required for paralleling pumps.
4. It has infinite speed selection over the narrow range in which the pump speed is changed.
5. It has reduced maintenance in the pump and feedwater valves, since they are no longer subjected to wasteful excessive pressure
6. It has lowered the pressure in the high-pressure feedwater heater.
7. By its declutching feature, it enables large motors to be brought on the line unloaded.

Load Changes on Boiler Feed Pumps

A paper entitled "Effect of Sudden Load Changes on Centrifugal Boiler Feed Pumps" was presented by **Igor J. Karassik** of Worthington Pump & Machinery Corp., **George H. Bosworth** of Bechtel Corp., and **B. J. Schmid** of Pacific Gas & Electric Co. This represents an "interim" study of the limitations which sudden load changes may impose upon the satisfactory operation of boiler feed pumps from the point of view of hydraulic conditions. The study is concerned only with feedwater systems embodying direct-contact heaters on the suction of the feed pumps. There are two types of serious hydraulic problems which may arise during transient load conditions, namely those caused by an interruption or reduction in turbine load and those resulting from a sudden increase in this load, only the former being considered in this paper.

During a sudden reduction of turbine load it is possible that the NPSH (net positive suction head) available for the boiler feed pump may be seriously reduced due to the fluctuating relations between the decaying heater pressure and the feedwater temperature at the suction of the pump. The magnitude and duration of this reduction will vary according to the load drop which is experienced.

To prevent cavitation at the impeller, a certain amount of positive head above the vapor pressure of the entering fluid is required at the suction of a centrifugal pump to provide energy in order to maintain flow and to compensate for entrance losses. It is the reduction of available NPSH below this value, with the possibility of resultant cavitation, that is of concern during load drop. The immediate effects which cavitation will have on multi-stage centrifugal boiler pumps are to limit capacity and to induce severe vibrations which develop when the first-stage impellers start to cavitate. Although some pumps can stand severe flashing induced by cavitation, no boiler feed pump will stand an unlimited amount of flashing and the resulting vibration.

Although, as the authors point out, favorable circumstances in specific installations may eliminate some of the symptoms and effects of sudden load changes, it is still advisable to consider these changes in steam power plant design.

Etiwanda—A Study in Overall Steam Station Economy

By W. L. CHADWICK* and E. H. KRIEG†

In this paper, presented at the ASME Spring Meeting in Seattle, which is slightly abridged in the following, the authors discuss the features of the new Etiwanda Steam Station of the Southern California Edison Company, particularly from the standpoint of its built-in economies. The plant is in the early construction stage.

THE Southern California Edison Company system is changing from a predominantly hydroelectric system principally because the more economical hydroelectric sites have been developed. Sufficient base load now exists to warrant the installation of high-efficiency, reheat steam-electric plants whereas, formerly, low annual load factor limited steam plants to moderate pressures and temperatures.[1] In these earlier plants quick pick-up from minimum to maximum load was required, a problem which the Company solved by the pioneer development of extremely wide-range oil burners. The system now has 748,000 kw of capacity, designed and adapted for quick load pick-up; hence, a new plant could be planned to exploit the improved load factor.

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[1] See "Steam-Electric Power Expansion in Southern California," by W. L. Chadwick, *ASME Trans.*, April 1950, p. 223.

Selection of Site

The Etiwanda Steam Station is being built in the heart of the growing Fontana industrial area, about 50 miles east of Los Angeles. Ocean front sites and other inland locations were considered, but the Etiwanda site was selected for the following reasons:

- It is in a rapidly growing industrial area where no fuel-burning plants now serve the Edison system.
- The area is still open for industrial development with favorable zoning.
- A desirable dispersion of stations is attained.
- Excellent transportation facilities, both rail and highway, now exist.
- Ample water makeup for cooling towers is available from the nearby main upper feeder of the Colorado River aqueduct, and good underground water is available in sufficient quantity for boiler makeup.
- Existing 220-kv right-of-ways provide routes for additional 220-kv circuits.

The site is being laid out for an ultimate capacity of 550,000 kw, but only two units, totaling 250,000 kw are presently being installed; the two future units may be larger.

Structures and Enclosed Spaces

The station is being built in a dry, warm climate where the average rainfall is about 17.5 in. per year with only a few hours of freezing temperature on a few days per year. It was natural, therefore, to limit enclosures to

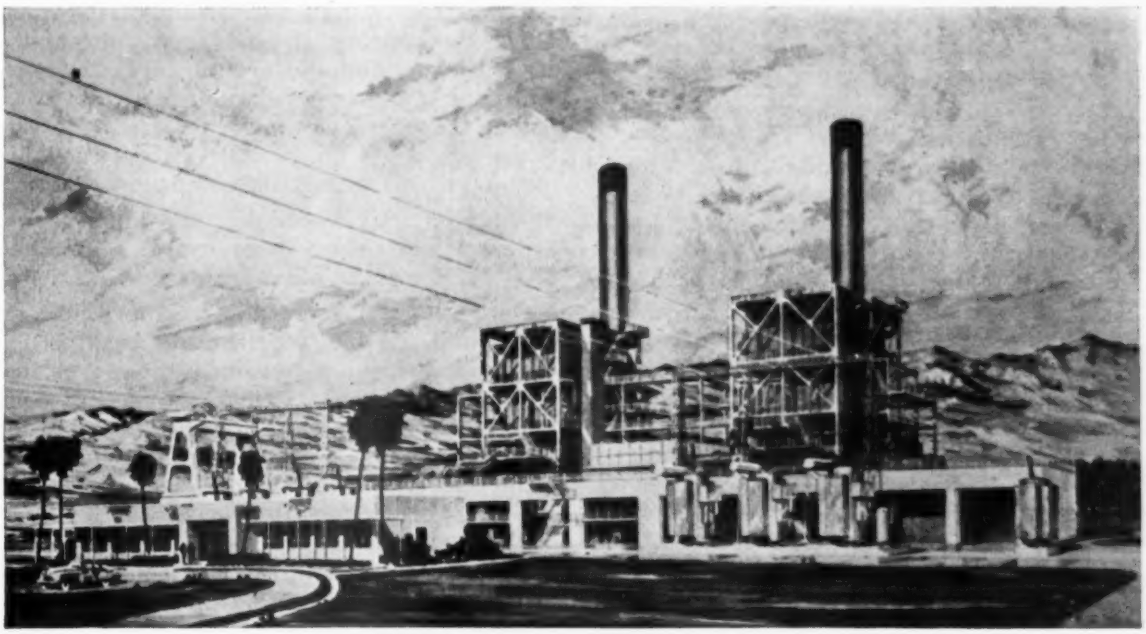

Fig. 1—Architects' rendering of the Etiwanda Steam Station

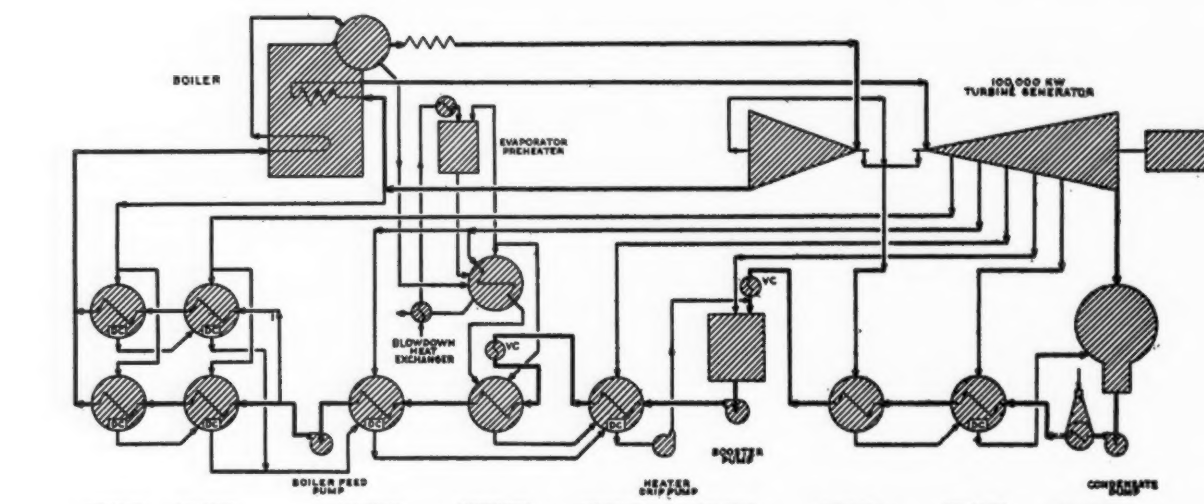

Fig. 2—Etiwanda heat cycle showing deaerator at 15 psia bleed point and two streams of heaters for two highest pressure bleed points

the control room, the administration building, shop, warehouse and water treatment building.

The Southern California Edison Company pioneered heat pumps in 1930, long before their currently popular use, and the same thinking was carried forward by heating and air conditioning certain enclosed areas with heat pumps. Study was made of both common and separate pumps. However, because the administration building will be occupied only about 40 hr a week, compared with 168 hr a week for the control room, it was found more economical to use a small pump to serve the former and a larger one for the latter. The air conditioning design criteria are to hold the office temperature in the warmest weather 20 deg F below the ambient and the control room 18 deg F below. To reduce the load on the air conditioning system, sunshades are being built over the administration building windows which will prevent direct sunlight entering the rooms, but admit plenty of reflected light.

Minimum use of enclosures greatly simplified the ventilation problem and resulted in an estimated saving of over $75,000 for ventilating fans. Consideration was given to the use of "walk-in" enclosures over the turbine-generators, but it was realized that the high ambient temperatures in the summer plus radiation from machine parts would, without excessively expensive cooling equipment, make these spaces stifling.

Two additional advantages of the outdoor construction are anticipated: one, a saving in clean-up labor through ability to wash down floors and equipment when necessary; the other, a gain in safety.

It is estimated that the total saving through elimination of the usual boiler and turbine buildings will be between $5 and $8 per kilowatt.

At a considerable economy, "tilt-up" concrete construction is employed for the one-story administration building where maximum use will also be made of formed surfaces for final finish. The walls are of concrete, cast and cured horizontally, using ready-mixed concrete, then "tilted-up" into position and the sections joined together. All structures were designed for a seismic factor of 0.2 g.

A 60-ton main gantry crane was selected to handle the turbine parts but not the generator stator. As the latter need be handled only once, it will be cribbed into place. Hence carrying charges on the larger crane will be saved.

Subsurface construction has been kept to a minimum. Because of the very favorable natural ground conditions and by using carefully compacted fills, forms were not necessary when casting column footings and most subgrade concrete.

Size Factor and Duplicate Installations as Major Economies

Keen appreciation of the savings afforded by using large units influenced the selection of the largest 3600-rpm tandem-compound turbine-generators being manufactured at the time, even though none was then in operation. The incremental cost of 125,000 kw over 100,000 kw capability units is less than the ratio 1.25 to 1. By designing and installing simultaneously two 125,000-kw units, each on a unit basis, substantial reductions are also being made in engineering, purchasing and construction. Engineering and drafting work is simplified for two units, purchasing for two units costs less, and, by having the second unit follow the first by a few months, major reductions are possible in construction costs as men have been trained and solutions to many problems have been developed.

Heat Cycle

Once the heat cycle of a steam-electric station is determined, its fuel requirements are frozen, because a change in fuel cost seldom justifies a change in the heat cycle of an existing plant. Frequently, insufficient time is available in which to study this most important design decision, and all too often it is left to the turbine manufacturer to suggest what heat cycle should be used, regardless of the fact that he can not investigate the many economic angles involved. The heat cycle is only one element in a complex of many factors requiring study, such as: hours of operation per year at various loads, optimum number of turbine exhaust flows, optimum size of condenser and cooling tower, and differential costs of

various steam pressures and temperature, keeping in mind that the vital fuel cost is not only today's, but a composite of today's and those of the next 10, 20 and 30 years.

Fig. 2 shows the heat cycle that was eventually developed to achieve a happy medium between high fuel efficiency and the fact that high fuel efficiency means nothing to a plant that is shut down.

As indicative of the care needed in such a study, the engineers in their early work on the heat balance had been given a gain of only 96 Btu for a change from 1450 to 1800 psi initial steam pressure. The decision to use 1450 psi was almost reached on that basis, but a background of experience with similar studies for other plants indicated that the difference between the two pressures should be 130 Btu. This immediately threw the balance strongly in favor of 1800 psi after a check showed the original figure to be erroneous.

Because of widespread experience with the fouling of closed low-pressure heaters, which have caused initial heater terminal differences of 5 deg F to increase to 15 deg F and even 30 deg F, it was early decided to use an open deaerating heater at as low a pressure as would be economical. This arrangement had been used before with satisfactory results at the Buzzards Point Plant of Potomac Electric Power Co. In addition to the objective of maintaining a close terminal temperature difference for the heater at a stage where it means the most, it was also desired to decrease the static head between the deaerator and the primary boiler feed pumps for two reasons:

To eliminate the expense of heavy steelwork required to support the heater at the usual 50 or 60 ft above the feed pumps, such as is required when a 50-psi heater is used.

To reduce the cost of earthquake bracing needed for a heavy deaerator at a high elevation.

The deaerator was finally placed at the next to lowest bleed point, which is at a pressure of 1 psig, or higher when the unit is operating at 80 per cent turbine capability and above. This arrangement minimizes the low load venting problem and decreases the cost of air removal equipment.

By placing the lowest pressure, or 6-psia, closed heater in the condenser neck so that piping between the turbine extraction connection and the heater inlet is only 4 or 5 ft long, the decreased bleed piping pressure drop has the effect of gaining 1 or 2 deg F on the heater terminal difference.

The complete study made to determine the most economical terminal temperature differences for the heaters and drain coolers led to the decision to use the following values at 125,000-kw load:

Heater No.	Condensate Terminal Difference	Drain Cooler, TD
1 (highest pressure)	−3	10
2	−3	10
3	0	10
4	+3	10
5 (deaerating heater)	0	None
6 (lowest pressure)	+4	10

The heat rate with 2 in. Hg back pressure is expected to be around 9540 Btu per kwhr sendout when operating on oil fuel and after full charge for the power needed for all auxiliaries, including the cooling tower induced-draft fans.

Turbine Generator

Selection of initial steam conditions and number of exhaust flows being the first decision necessary preparatory to the selection of other equipment, detailed cost analyses were made to determine the most economic combination of initial steam conditions, cooling tower size, condenser size and number of turbine flows, that is, whether double or triple flow. Further, the use of a cooling tower made it necessary to study the economics of the combination simultaneously, as a change in any one of these variables would definitely affect the choice of the other variables. The optimum combination was found to be:

Initial steam conditions of 1800 psig, 1000 F with 1000 F reheat.

Triple-flow exhaust (partially justified in anticipation of outputs somewhat higher than 125,000 kw).

Cooling tower with 14-deg F approach, giving 72 F water with a 58-F wet bulb.

80,000-sq ft condenser for yearly average vacuum of 1.65 in. Hg.

A special study was made by the General Electric Company on turbine-generator appearance, including preparation of a model that served as a prototype for many other units, because it was believed that a machine, costing several million dollars, should "look like a million dollars."

Among other means utilized to obtain economy is an unusual emergency stop-valve arrangement which permits vertical and axial, but no lateral, movement, both simplifying and minimizing the cost of the main steam leads as well as the piping between the stop and control valves. A shaft-end house generator will be provided on each unit.

Steam Generating Unit

The selection of controlled-circulation boilers was based on economic comparisons which included both purchase price and the comparative cost of supporting steelwork.

Controlled circulation facilitated the use of 1800 rather than 1450 psi turbine inlet steam pressure. The 3-in. OD tubes normally furnished with 1800-psig natural-circulation boilers are suitable for 2010 psig, whereas the 1.5-in. OD tubes of the controlled circulation boilers are suitable for a pressure of 2332 psig. With negligible cost for thicker drums, 1950 psig superheater outlet pressure or 50 psi above that available with natural circulation was obtained. Being able to allow 50 psi higher presure drop in the main steam leads made possible the use of 10.5 in. OD rolled tubing, rather than larger diameter forged and bored tubing costing about $150,000 more. As controlled circulation boilers employ tubes of smaller diameter with correspondingly thinner walls, the skin temperature is less for equal rates of heat absorption than with natural circulation boilers. With lower skin temperatures, it is anticipated that maintenance may be somewhat less and availability somewhat higher.

Controlled circulation also makes it possible to provide water-cooled spacers for the superheater and reheater which should reduce attack by fuel oils producing metallic oxides, particularly those of vanadium. Such fuel oils

cause serious maintenance of superheater spacers even when made of 25 chrome-12 nickel alloy.

Other advantages considered for controlled circulation are:

- The boiler is about 13 ft lower and about 125 tons lighter, which is an advantage when designing for earthquake conditions.
- It should be possible to restore a boiler to service more rapidly if a tube failure should occur.
- The ratio of steam to water passing through the drum separators is greater because only about one-third as much water is circulated.

Because oil is expected to be the major fuel, turbine bleed steam will be supplied to the coil of steam air heaters between the forced-draft fans and the main regenerative air heaters to minimize deposits and corrosion on the cold end. This will be done the year round, even in summer months. The air entering the regenerative air heaters will be heated to maintain the air inlet end of the revolving elements at an average metal temperature of 215 F.

Experience with many oil-burning installations has shown a need for frequent removal of deposits from cold-end air heater surfaces. Etiwanda will be one of the few installations designed to permit water-washing such surfaces without taking the boiler out of service. Air soot blowers will be provided but, should these be unable to remove the expected deposits, washing will be done under load thereby saving fuel by maintaining boiler efficiency and improving availability at small investment cost.

Cooling Tower

To adhere to the ideal of a simple, rugged and economical installation, a cooling tower common to both units was planned to minimize first cost and simplify maintenance. The foundation design is unusual and comprises a plain flat slab, omitting even pedestals for column bases. This construction avoids the usual basin and its cleaning difficulties. Seldom is it realized that a cooling tower for an installation like Etiwanda must handle 4000 cu ft of air for each kilowatt-hour, or a 250-ft cube of air per minute for full load of 250,000 kw. As the district where the plant is located is subject to unusually continuous winds of varying intensity, provision is being made to handle the dust, leaves, tree bark and insects that may, at times, be collected in the cooling tower system. With the flat slab base, such debris can easily be hosed into the open gunited discharge flume and removed at the central settling chamber in the flume. Furthermore, less distance between the bottom cooling tower fill and the slab will make maintenance more convenient than the usual deep basin.

The possibility of exploiting the favorable wind condition to the maximum by the most advantageous tower orientation was investigated, i.e., parallel or normal to the prevailing wind. However, few data are available on the isotherms to be expected on the lee side of cooling towers in any particular position. Particularly are data unavailable on recirculation as affected by tower orientation. Other major considerations were avoidance of recirculating vapor to future towers and minimizing drip or fog effect on plant working areas. These studies led to positioning four 145-ft long sections of tower nearly normal to the prevailing wind direction with 85 ft between sections. This layout should give optimum performance for the 835-ft length.

The cooling tower makeup problem was accentuated by the necessity of using Colorado River water having about 750 ppm of dissolved solids. Also, this is expensive water, as it must be raised by pumps a total of 1618 ft and transported more than 250 miles from Parker Dam across the intervening desert before reaching the plant.

A treatment plant will stabilize the cooling tower makeup which is relatively high in dissolved solids, in order to allow higher concentration, hence minimize blowdown. This result will be accomplished by maintaining a suitable Langelier saturation index to avoid deposition of scale on the condenser, hydrogen and oil-cooler tubes, on the one hand, and to avoid the corrosion attendant on excessive acidity on the other.

Special attention is being given to means for handling fan parts during maintenance and overhaul to keep down the size of maintenance crews. A one-ton gantry crane made from piping and built to travel along the tower top will lift and transport motors, gear boxes or fan blades to one end of each tower section where they may be lowered to the ground through a trap door.

Where possible, open gunited flumes are being used for conveying the 140,000 gpm of circulating water, that type of conduit being considerably more economical than the 8-and 9-ft ID precast concrete pipe being used elsewhere.

To provide cooling water makeup for a few days should the aqueduct water supply be interrupted, a 40 acre-ft (13,000,000 gal) storage basin is being built on the site. This basin is formed of rolled earth-fill dikes constructed by the modern earth dam techniques. A gunite lining will be provided to avoid loss of water and the risk of damage to the basin by rodents and erosion.

Condensing System

Among the unusual features of the condensing system will be the use of a large-capacity reciprocating dry-vacuum pump as a "hogging" jet for rapidly evacuating the steam spaces, as well as to back up the single set of steam-air ejectors and allow starting the turbine-generator at about 100 psig steam pressure.

A rubber expansion joint between turbine and condenser is being provided to avoid throwing any heavy earthquake load on the turbine.

Feedwater System

Deaerators are usually placed at a 50 or 60 psia bleed point in order to avoid vacuum operation, but the Etiwanda deaerator will operate at a 15 psia pressure at turbine loads of 80 per cent capacity and over and will be provided with equipment for automatic removal of noncondensable gases during partial load operation.

As shown by Fig. 2, the heaters on the two high-pressure bleed points are in two streams because four smaller heaters proved less expensive than two large ones. It was also possible to eliminate heater by-passes as all the condensate can be passed through either stream, hence there is less effect on station capacity when removal of a heater from service is necessary, there being less

lowering of feed temperature and disturbance of boiler temperatures.

Boiler makeup will be obtained from wells on the site. This water will be pretreated to reduce hardness and alkalinity before sending it to the evaporators.

Two 100,000-gal tanks will provide condensate storage.

Piping

The gate valve between boiler and steam turbine was omitted to save the first cost of $36,000 for two units and because valves are often a cause of outage.

Design of the main steam leads started with the ideal objective of having two equal straight runs arranged like an "L," one downward from the superheater outlet, and one continuing horizontally to the turbine. As the design of the plant developed, a few compromises were necessary in the layout in order to avoid interference with large steel members, particularly earthquake bracing and gusset plates, to change which would have cost far more than modifying the piping.

Careful comparisons were made of the cost of providing flexibility in the main steam leads themselves as against rigid piping with a flexible superheater outlet header, which would have cost $25,000 per boiler. Designing the steam leads with more flexibility proved cheaper. However, this was not the case with the 16-in. OD, 1-in. wall hot reheat piping having some 8.7 in. expansion per 100 ft. In this case it proved far more economical to use a flexible or movable outlet header which would follow the vertical movements of the piping. On the other hand, providing inherent flexibility in the cold reheat piping proved more economical than building a movable cold reheat header.

To attain simplicity, the policy of creating as few interconnections as possible was followed; operating experience having shown that they often cause as much outage time as they save, if not more. There will be no steam or feedwater interconnections between units. Furthermore, to reduce piping, insulation and valve costs, the use of auxiliary steam has been reduced to a minimum, it being used only for oil heating and normal air ejection. Soot blowing will be performed by air stored at 500 psig and supplied at 350 psig.

Other means used to reduce investment in piping were:

- Elimination of many pipe trenches by backfilling the trenches containing bare steel pipe with oil saturated soil.
- Two fire systems, one at the station served by two pumps backed up by the service water system, and the other at the oil tanks and cooling towers. This proved more economical than a single system because the tanks and towers will be remote from the rest of the station. Safety and reliability were also improved because the equipment is more dependable than the long interconnecting piping.
- Normally, two steam supply lines would be used for fuel oil tank heaters, but only one is being constructed with the provision, in case of emergency, for use of the condensate return line for steam supply, temporarily wasting condensate during such infrequent use.

Inasmuch as the height of the turbine deck for this station was reduced to the minimum because of seismic forces, less than a 24-ft high space is available for piping and auxiliary equipment beneath the turbine deck. To provide an economical and orderly piping arrangement, the layer system of piping was used with all main north-south runs at one grade and east-west runs at a different grade.

Instrumentation and Control

The centralized control room is being built between the boilers at the same level as the main turbine operating deck. The control boards have been kept to minimum length to simplify actual operation and for operator convenience while restoring service after an emergency trip-out. Ample time is almost always available to start a unit from cold, but this is not so when restoring service after a trip-out. To this end, only those instruments actually required for controlling the turbine, boiler and auxiliary equipment are on the front of the board, while recorders, supplying historical data primarily for result purposes, are placed on the back of the boards. Fig. 3 shows the compact control room; the boiler turbine boards being only 17 ft 3 in. long for each unit.

Pressure and flow measurements will be telemetered electrically or pneumatically to the control room from local transmitters so that only low-pressure lines will

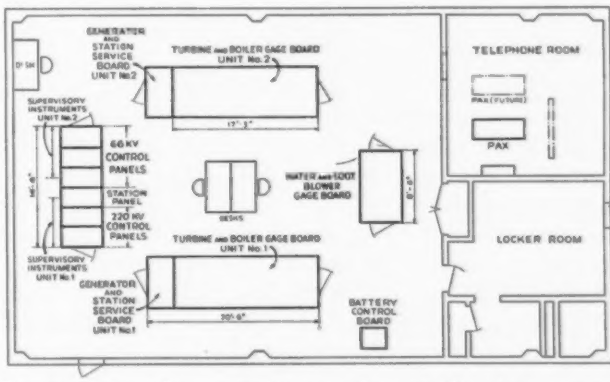

Fig. 3—Etiwanda control room layout showing compact turbine-boiler-electrical control board

be brought into the control room, thereby minimizing the hazards to operators and equipment.

If the turbine stop valves close simultaneously, relays will automatically decrease fuel supply 80 per cent in order to prevent the reheater from overheating as well as to maintain fires for an immediate restart without delay for lighting off. Upon closure of both stop valves, relays will also automatically open the main generator breaker after a five minute delay.

The combustion system is designed to control oil and gas separately, or in combination, with automatic adjustment of either as "swing" or "base" fuels.

Televising the Furnaces

In the interest of reliability and availability, two flame Utiliscopes are being provided per boiler, one for each half furnace, so that the condition of all portions of the eight flames as well as the ignition torches in each

half furnace can be seen in the control room. Initially, this seemed a difficult task to accomplish because the single previous installation of such equipment had used a roof camera setting, but such a setting for the Etiwanda boilers would have caused a most difficult cooling problem as the Utiliscopes would have been in a deep hole between the boiler roof and the upper furnace tubes. This problem was solved by using "bay windows" formed by simply bending tubes inward in the upper front wall.

Although automatic starting of essential spare pumps has been provided, direct control of important pumps is being provided to the control room operator.

Valve control has been generally centralized in four areas of the plant rather than being scattered. All valves for feed pumps, extraction steam lines and heater drainage piping will be grouped on a mezzanine grade beneath each turbine. Valves for fuel gas, fuel oil, boiler drains and boiler feedwater control are also on the same mezzanine grade, alongside each boiler. Valves for fuel oil heating and condensate returns for the fuel oil heaters are at a third location beyond the draft equipment at ground grade, and control for fuel oil pumping is provided at a fuel oil pumping station centrally located between the four 130,000-bbl fuel oil tanks.

All valves are being so located that they may be operated, packed or serviced without the use of ladders, scaffolds or auxiliary platforms, and none will require extension stems or chain wheels. A few valves will have floor stands.

Maintenance

Currently, much emphasis is being placed on reducing the number of plant operators to the minimum and one frequently hears that a particular plant has only about six operators per shift, without mention of the men required on maintenance. In the modern plant, the maintenance crew is usually appreciably larger than the operating crew. Although Etiwanda will meet the optimum criterion with only six operators for two 125,000-kw units, close attention has been given to minimizing the maintenance organization by simplifying its work, such as by providing:

- Well pitched floors and adequate drains so that all unenclosed concrete floors may be hosed down without the need for sweeping or using vacuum cleaners.
- Portable gantrys for handling cooling tower parts and light turbine parts during maintenance or overhaul.
- Davits for handling heater parts.
- Hoists for handling circulating-water screens and certain outdoor pumps.
- Space around all equipment and motors so that fork lift trucks may be used to handle heavy parts, especially those on ground grade and on concrete floors. This provision has minimized expensive monorail hoists.
- Galvanized open grating platforms to eliminate floor cleaning and future painting.

A simple machine shop is being provided with the minimum number of machine tools. Because the Company has a good machine shop at its Long Beach Steam Station, only 50 miles away, and there are excellent custom shops available, the Etiwanda shop will be used as now provided until justification for additional tools is clearly established.

Electrical Features

Generator output will be raised from 15.5-kv to 220-kv system transmission voltage by separate transformer banks serving each generator.

Economic studies were made of various transformer combinations, that is, of the possibilities of using three-phase transformers and of various basic insulation levels. Because of railroad clearances for the long cross-country haul involved, as well as first cost disadvantage, three-phase transformers proved uneconomical for the ratings involved. The Company has previously used 1050-kv as a basic insulation level for all recent 220-kv transformers on its system, but studies for Etiwanda showed about $170,000 saving by using an 825-kv basic insulation level and providing arresters.

Study was also given to the use of isolated phase generator lead construction, but this proved uneconomical for all except the runs below the turbine deck. Elsewhere, the runs will be aluminum channel on post-type insulators, protected by gratings above and screens below. The resultant saving is in the order of $70,000.

Space is being provided for a 66 kv outlet when needed to serve local requirements.

Unusual Problems

Because the water from the cooling towers will have a concentration of about 3000 ppm, it will not be wasted to storm drains in order to avoid possible percolation into the ground water basin. A waste-disposal system will be built in conjunction with the established disposal agencies in Los Angeles County to convey all industrial waste approximately 50 miles to the ocean. This disposal will require construction by the Company of a 15-mile concrete pipe line of 5-cfs capacity to connect with existing trunk sewers in which capacity will be purchased.

Three means of transporting fuel oil to the station were studied, including pipe line, truck and rail. Because of the large savings involved, an $8^5/_8$-in. OD pipe line will be built about 40 miles across country from Santa Fe Springs to Etiwanda with three heater pumping stations to divide the line approximately into thirds. Initial temperatures of 200 F will be necessary to avoid excessive pressures during winter conditions. Electrically driven reciprocating pumps will provide 800 psig pressure for flows of from 400 to 700 bbl per hour. Heating will be by means of direct-fired tubular heaters of the type common to the oil industry.

Closure

Acknowledgment is gratefully made to Mr. John Bruce and other operators who participated in the design discussions, to Mr. T. M. Hotchkiss and other engineers of Southern California Edison Company, and to Mr. W. C. Woodman and other engineers of Stone & Webster Engineering Corporation, who all realize that no plant is the work of one person, but the result of the efforts of many. It is believed that the Etiwanda Steam Station will mirror the desire of Southern California Edison Company to provide steam-produced electrical energy to its customers at minimum cost and maximum availability.

Increased Interest in Smoke Abatement Focuses Attention on Electrostatic Precipitation

By W. W. MOORE and H. L. RICHARDSON
Research Corporation, Bound Brook, N. J.

During the last fifteen years there has been a demand for ever-increasing efficiencies in fly-ash removal, particularly the extremely small particles. Such guaranteed efficiencies are listed. The principle of operation of an electrostatic precipitator is explained and illustrated, and a recently developed continuous or sequential rapping system that avoids puffs is described.

MUCH has been said and written in the past twelve months about smoke and air pollution and what should be done about it. Municipal authorities in such cities as New York, Pittsburgh and St. Louis have taken steps aimed at enforcing smoke abatement programs.

Power plant engineers do not find themselves confronted with any new problems as a result of this recent activity which seeks to reduce the smoke nuisance. That public utilities have long recognized the need for fly-ash elimination is indicated by the fact that the first electrostatic precipitator was installed for this purpose in 1923. Today, electrostatic fly-ash collectors form an integral part of many pulverized coal-fired boiler installations. They are included in power plants chiefly because management appreciates the importance of public interest and community responsibility.

The magnitude of the fly-ash problem is indicated by recently published figures covering the pulverized coal burned annually by utility companies alone, some 65 million tons. On a reasonable basis of an average ash content of 10 per cent, the quantity of fly ash that could be emitted would be about 5 to 6 million tons in one calendar year.

A large modern boiler producing, for example, 900,000 lb of steam per hour will discharge flue gas at the rate of about 450,000 cfm at 300 to 400 F. With a fly-ash concentration of two grains per cubic foot, which is a common figure, the dust emission will be approximately 130 lb per minute or 93 tons per day. This example serves to illustrate the magnitude of the problem involved in preventing atmospheric pollution from this source.

At present there are no generally well-defined regulations as to the amount of dust that can be emitted without constituting a nuisance. The American Society of Mechanical Engineers has prepared sample sections for smoke-regulation ordinances looking toward realistic and economically possible control.

In general terms, the ASME code gives a maximum figure for dust emission of 0.85 lb per 1000 lb of gas, adjusted to 50 per cent excess air and a maximum required collector efficiency of 85 per cent. Despite this, users of pulverized coal, and this applies particularly to the utilities, have set for themselves the objective of procuring equipment that will provide the highest possible collection of fly ash, both quantitatively and visually. This situation has led to focusing attention on electrostatic precipitation.

Electrostatic precipitation has been employed in many applications other than fly-ash separation. In many of these installations, efficiencies in excess of 99 per cent in continuous commercial operation are not unusual. In ash separation, the conditions under which a collector must operate vary from installation to installation and in day-to-day operation. Inasmuch as it is not ordinarily practicable to adjust these conditions for best collector operation, the precipitator must provide required performance under whatever conditions prevail.

TABLE 1—DIAMETER OF PARTICLES IN MICRONS

Sample	0–5, Per Cent	5–10, Per Cent	10–20, Per Cent	20–44, Per Cent	44, Per Cent
1	25	17	18.5	25.5	14
2	37	19	21	16	7
3	34	32	20	4	10
4	38	28	18	15	1
5	40	24	21	13	2
6	21	21	35	16	7
7	28	24	21	16	11
8	48	18	21	11	2
9	40	19	19	12	10
10	47	21	19	12	1
Average	35.8	22.3	21.4	14.1	6.5

The fly ash itself is a major variant. It is not a homogeneous or a uniform material. Its physical and chemical properties vary widely, depending upon such factors as type of coal burned, type of furnace, furnace operation and coal grinding conditions.

TABLE 2—DIAMETER OF PARTICLES IN MICRONS

	0–5, Per Cent	5–10, Per Cent	10–20, Per Cent	20–40, Per Cent	40, Per Cent
Average	11.91	17.66	27.08	18.65	24.70

Table 1 shows the fly-ash particle size analysis for ten actual samples taken recently from commercial operation of precipitators. From this data it is obvious that a high removal of extremely small particles is necessary in order to obtain a visually clean stack discharge.

In comparison, Table 2 shows the computed average of

seventeen fly-ash samples tested in 1938–1939. The trend, therefore, appears to be toward finer and finer particles.

Table 3 shows a comparison of the guaranteed removal efficiencies for all Research Corporation precipitator installations made during the years 1936–1950, inclusive. It will be noted that in the five-year period 1936–1940, only 22 per cent of the installations specified over 92½ per cent fly-ash removal efficiency. In the period 1941–1945, 60 per cent of the installations were above 92 per cent efficiency, and in the five-year period 1946–1950, 69 per cent of the installations were above 92 per cent efficiency.

The trend toward higher efficiencies as shown by the data just cited, is proof that power plant engineers in this country have been doing an increasingly better job of smoke elimination during the last decade, especially so in the five years since the end of World War II.

The principle of electrical precipitation is neither complicated nor new. Its simplest demonstration is the

TABLE 3—SHOWING FLY-ASH PRECIPITATORS INSTALLED BY RESEARCH CORP DURING 15-YR PERIOD. COLUMNS CLASSIFY THE NUMBER OF INSTALLATIONS (IN PER CENT OF TOTAL) WITH RESPECT TO FLY ASH REMOVAL EFFICIENCY

	Efficiency			
Years (inc.)	Below 90 Per Cent	90–92½ Per Cent	92½–95 Per Cent	95–97½ Per Cent
1936–1940	None	78	17	5
1941–1945	1	39	55	5
1946–1950	10*	21	47	22

* Includes precipitators in combination with mechanical collectors.

familiar grade-school experiment with static electricity. Remember rubbing a rubber comb or fountain pen with a silk cloth and watching it attract dry dust or lint? An electrical precipitator is essentially the practical application of that elementary experiment.

As early as 1771 observers noted the effect of electrical discharges through smoke-filled gases. Throughout subsequent generations many independent investigations were made of this principle, but due to the primitive nature of electrical generating devices, precipitation remained only an interesting laboratory phenomenon. It was not until 1905 that Dr. Frederick Gardner Cottrell, Professor of Physical Chemistry at the University of California, concluded a series of laboratory experiments that resulted in the installation of the first commercial precipitator. The practical success of this pilot unit soon led to others and to wide use of the process.

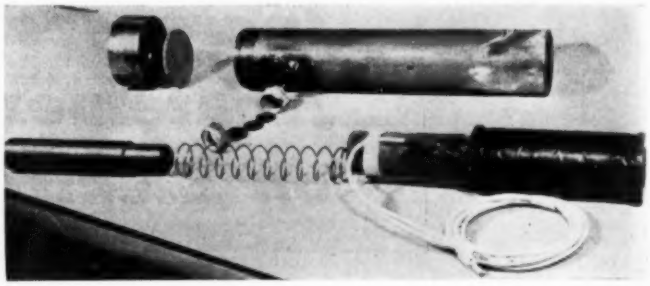

Fig. 2—Elements of the MI (magnetic impulse) rapper

The function of a precipitator is to collect liquids and solids suspended in industrial gases. Smoke, for example, is a suspension of small, solid particles in such density that they can be seen. Remove these solids and only the invisible gas remains. The Cottrell electrical precipitator performs this function by placing electrical charges on the particles as they enter a strong electrical field. In practice two groups of equipment are required: the electrical apparatus for producing and controlling the high-voltage power, and the precipitator chamber in which the gas is treated. Fig. 1 shows, schematically the principal parts that go to make up a typical installation.

Connected to any source of alternating current is a switchboard equipped with the necessary meters and controls. This is the operating center of the system. Current flows from the switchboard to a high-tension transformer which steps up the power supply to the required voltage for the particular purpose. This may be from 15,000 to 100,000 volts, or over. Since unidirectional current is essential, the stepped-up alternating current from the transformer goes to a rectifier for conversion. This rectifier is mechanical, but this conversion can also be effected by electronic tubes. Where the original power supply is direct current, it is necessary to convert to alternating current prior to raising the voltage and then rectifying back to direct current.

A conductor, usually a specially designed high-voltage cable, carries the rectified current from the electrical set to the precipitator. The precipitator chamber is shown at the extreme left of the diagram. Essentially, this chamber consists of grounded collecting-electrodes—here shown as a pipe. Suspended in the central axis of this pipe is the discharge electrode, which is carried

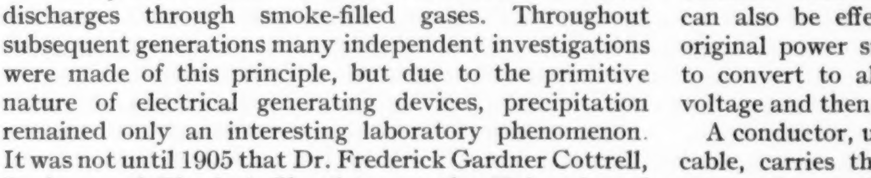

Fig. 1.—Schematic diagram of the equipment used in the Cottrell Electrical Precipitator. From left to right: precipitator, rotary rectifier, transformer, switchboard and supply line.

on insulators and connected to the source of the high-voltage current. The great difference in voltage between the discharge electrode and the collecting electrode sets up a powerful electrical field between them.

In this field a negative discharge from the discharge electrode forms negative gas ions which attach themselves to the suspended particles. The resulting negatively charged particles are attracted to the positive collecting electrode, where their charge dissipates, leaving them electrically inert. If liquid, the material collected flows down from the collecting electrode. If solid, the material is removed by special scraping, rapping or washing devices not shown here. All materials are deposited into the hopper at the bottom of the chamber, from which they are readily removed for disposal or use.

The type of electrical precipitator most generally used for removal of fly ash in power plants is the horizontal-flow plate unit. It consists of a series of parallel plates encased in a shell, thus forming ducts or gas passages. The discharge electrodes are suspended in the centers of these ducts from an insulated framework. This type is the natural design for most power plant equipment arrangements, and it can handle large gas volumes and quantities of ash at minimum cost. The vertical flow type of electrical precipitator, which incorporates hollow steel plate collecting electrodes with protusions or louvers on the surface, is used to meet specific installations problems. This type is primarily used where space limitations prevent the use of the horizontal flow unit, or where the chemical characteristics of the fly ash dictate its use.

It is evident that each particular installation must be engineered to serve specific requirements. Special features of design and construction, therefore, are employed to produce optimum performance based on extensive experience and practice with this type of equipment in the field. Modern steam generation, with higher capacities in less space, makes it necessary to study each case at length in order to get adequate precipitation capacity into areas which become smaller as the years go by.

New Developments

Recent advances in the development of a new rapping system for collecting fly-ash particles at higher efficiencies are particularly important to the power field. Since all of the fly ash precipitated does not settle by gravity into the hopper below, and an appreciable layer of fly ash gradually accumulates over the plate surface of the collecting electrodes, the rapping system used for unloading this accumulation becomes a vital phase of the operation.

In the past the rapping system was intermittent. At periodic intervals the dust was shaken loose from the collecting electrodes by mechanical or pneumatic means. With this intermittent rapping and the weight effect of large batches of fly ash dropping into the hopper, some of the collected dust would re-entrain in the flue gas and escape through the stack in visible clouds or rapping puffs.

Although the actual dust loss during the rapping operation was only 2 to 3 per cent, public asperity grew and was not mollified by technical explanations. Dampers were closed during the rapping operation to eliminate these undesirable rapping puffs. Various types of pocket or hollow collecting electrodes were also tried. But neither these methods, nor the many others devised, were more than partially effective.

Advantages of Continuous Rapping

Recently, however, a new rapping system based on magnetic and electric principles has been introduced as a satisfactory answer to this problem. It is a magnetic impulse-type rapper capable of delivering continuous or controlled sequential rappings. The collecting plates of the precipitator are sub-divided into separate banks and each bank is vibrated or rapped sequentially at least once every second 30 sec, depending on the number of banks. Each bank may be rapped more often than every 30 sec.

With this method precipitation is converted from the previous batch operation to a more desirable continuous, uniform operation. Collecting electrodes are cleaned at a continuous rate, thus preventing major disturbances in the hopper caused by large batches of precipitated dust. Dust re-entrainment in the flue gas resulting from hopper disturbances is eliminated, and along with it the rapping

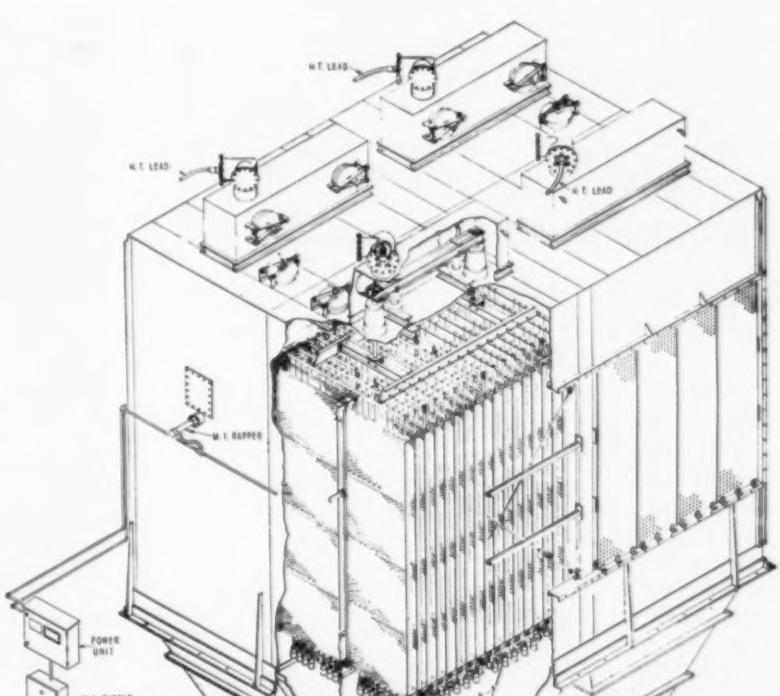

Fig. 3—Schematic position of power unit in line with magnetic impulse, remote-control panel, magnetic impulse rapper, and electrical precipitator

puffs that are always associated with intermittent type rapping. The new continuous rapping system makes it possible to maintain a continuously clean stack with no rapping puffs or clouds.

The elements of the magnetic impulse-type rapper are shown in Fig. 2. The operating element is the electromagnet unit consisting of a solenoid coil and a steel plunger driven by electromagnetic energy. Also shown are the lead wires and the seamless steel housing with its exit nipple and external fixtures for terminal connections.

Pulse energization is used for this type rapper and it is supplied by a special power unit. The input to this system is 115-volt, 60-cycle power. Components of the special power unit are the transformer, thyratron tube, rectifier tubes, condensers and a distributor switch with a timing motor. Fig. 3 represents the schematic position of such a unit in line with a magnetic-impulse, remote-control panel, magnetic impulse rapper, and electrical precipitator.

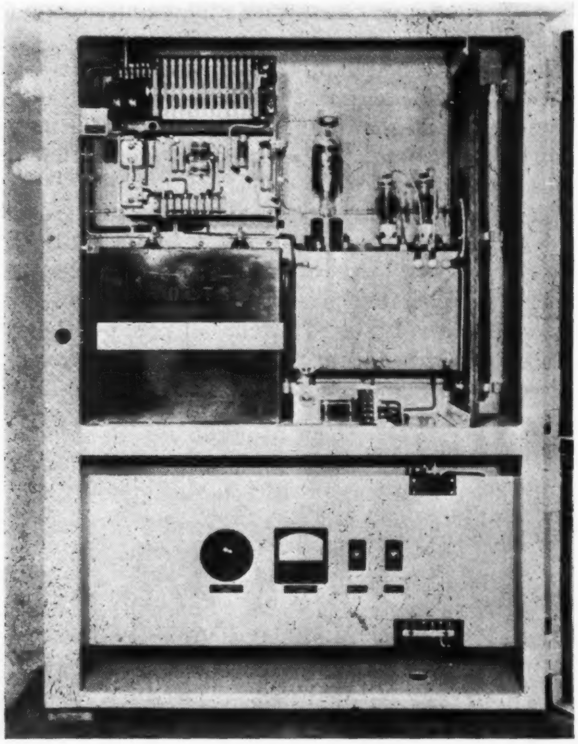

Fig. 4—Cutaway view of magnetic impulse rapper control and power unit combine in weather-proof cabinet. Upper panel contains power unit and the lower panel the control unit.

Principle of Operation

The general principles of this system are that the condensers are charged over a timed period, then discharged at a rate controlled by means of the thyratron tube and distributor switch. The solenoid coil, excited by the impulsive discharges of the condensers, generates the electromagnetic force for driving the steel plunger which delivers the rapping action. Both the intensity and frequency of the rapping cycle are adjustable to meet varied requirements. A number of rapper units, up to twelve or more for a large precipitator, may be energized from one power unit.

Fig. 4 is a cutaway view of the magnetic-impulse rapper control and power unit combined in a weatherproof cabinet which is mounted near the precipitator to conserve wiring.

The rappers of the magnetic impulse rapping system are welded directly to the rapping bars of the precipitator in present installations. Complete control plus surveillance of operation are incorporated in a remote control panel, which may be placed in any desired location. The upper panel contains the power unit and the lower panel the control unit.

With the desire of industrial plants to obtain cleaner stacks, there is no doubt that interest in electrical precipitators and magnetic impulse-type rappers will increase. There are, of course, many problems involved in the specific installations. Electrical resistivity of the dust, gas velocity and flue arrangements are important variables which have to be taken into consideration. Size shape and type of both discharge and collecting electrodes, their relative spacing, and the amount of electrical energy are design characteristics of each particular application. Nevertheless, it is hoped that the information given here will be helpful to plant engineers in solving their problems of smoke abatement and fly ash elimination.

The Fuel Problem in Italy

By GIOVANNI COPPA ZUCCARI

A review of the fuel supply of Italy, as bearing on her economic situation. Industrial recovery has been accompanied by greatly increased fuel demands which are being met by brown coal from Sardinia and imported coal from other European countries and the United States. Also, there is an abundance of natural gas but very little native petroleum; hence the refineries must be supplied with imported oil.

THAT Italy has practically no fuel of its own and must import large quantities of coal and petroleum, is well known, but the exact situation that prevails is not so widely known. Importers of coal naturally think in terms of bigger and better imports; producers of brown coal in Sardinia, humanly enough, want to press their inferior (but not worthless) coal into every use and to market promptly the whole of their output. Then there are the sponsors of electric power and the ever-growing petroleum refineries which have their own points of view. Recently, another group has been added, namely, the methane producers. Encouraged by the ever-growing output of methane gas they want to push their product at all costs. Utilization of this gas has spread greatly in Northern Italy, but some technicians are busy on colossal projects of pipe lines that would bring methane from Northern Italy to Rome and to Naples. To listen to them one would come to believe that importing coal and oil is for Italy a foolish and money-wasting occupation.

For this reason the recent statements of Mr. Campilli, Italian Minister of Industry, are particularly valuable as they give an impartial picture of the situation as seen by a man who does not represent a particular industry but is entrusted with the task of looking after the general well-being of his country. In fact, his statements elucidate the following solid facts that are not lacking interest.

Until comparatively recently the annual requirements of Italy in imported coal were reckoned at about 750,000 tons. At present, owing to industrial recovery, this figure has risen to about a million tons monthly.

Industrial Recovery Increases Fuel Demand

Up to March 1951, however, the supplies of coal were not always reliable, inasmuch as, owing to shortage of dollars, Italy had to look for coal to those European countries that buy her products and repay her in coal. This was a natural enough arrangement but whenever a hitch occurred in the European output of coal, Italy had to suffer. The situation finally was remedied by imports of coal from America and today the situation is reasonably hopeful.

Furthermore, the industrial recovery of the country has proved a life-saver for the coal mines in Sardinia which had been suffering from a crisis for some time. Not only were these Sulcis mines able to dispose of their burdensome stock of brown coal but they have been able to secure advantageous orders for future deliveries. At present the management of these mines is building a new and up-to-date washery which will start working in 1952 and which will enable them to improve considerably the quality of the coal produced.

Italian Refineries Expand

As regards fuel oil, its consumption is constantly growing in Italy, and although Italian refineries have increased their output by 40 per cent over that of 1950, the production proved inadequate to meet the demand and some 500,000 tons of residuals had to be imported for fuel. However, as some Italian refineries are being expanded, it is thought that they will soon be able to cope with the increased demand.

There has been a considerable increase (about 20 per cent) in the output of coal gas. The fully reconstructed and, in some, cases enlarged and modernized Italian gas works now turn out about 3 million cubic meters of gas daily. The heating value of the gas is back to 3500 calories and it is planned to increase this further in order to compete with methane and liquefied gases which are steadily gaining ground. In fact, in some instances the producers of coal gas and those of methane are tending to cooperation, for during 1951 city gas works were scheduled to distribute 40 million cubic meters of methane mixed with their coal gas.

The use of liquefied gases (butane and propane) is spreading rapidly in rural districts where housewives appreciate greatly their convenience compared with wood or charcoal. By now about a million homes use this type of fuel. The petroleum refineries awoke quickly to this new field which provides them with an excellent outlet for butane and propane as derived from their manufacturing processes, and prospective users are now enticed by the offer of cooking ranges on the installment plan, gifts of the first lots of gas, etc.

In fact this supply of heat has become so important that the Government is promulgating a series of regulations to guarantee the safety of users and to control the distribution.

The consumption of natural gas (methane) now exceeds three million cubic meters daily and is still continuing to grow, although not at the same rapid rate as the available supply which, by the end of 1952, is expected to reach ten million cubic meters a day.

It is not clear how the present consumption could be tripled. The promoters of methane suggest replacement of other types of fuel by methane in all branches of national activity, but Mr. Campilli pours cold water on this idea. He admits that, from the point of view of calories alone, a daily consumption of one million cubic meters of gas would enable Italy to reduce her imports of coal by 500,000 tons, but this would not be so, as the economic value of a cubic meter of gas depends on the use to which it is put and the value of the goods manufactured.

There are also other and very important considerations. Italy has to export a certain range of goods to European countries which can pay for them only in coal. Thus she is obliged to take coal from them or give up these export markets. The motorization of the country is demanding from Italian refineries ever-growing quantities of gasoline for automobiles. More gasoline means more fuel oil which must be marketed. Thus, desirable as it might be, the substitution of methane for fuel oil would stifle the Italian refineries. Furthermore, there are the Sulcis mines of brown coal in Sardina. Millions have been sunk into them by the E.R.P. and the Italian taxpayer to modernize them and to increase their output threefold. This output must be marketed.

All these factors show that there are sound economical reasons which prevent a wholesale adoption of methane gas in Italy. These factors oblige Mr. Campilli to frown at the enthusiastic projects of some technicians who talk in the terms of a trans-Italian pipe line that would carry the gas from one end of the country to another, expecially as such projects involve enormous amounts of steel and heavy financial outlay.

Methane as a Source of Power

Instead, the Italian Minister of Industry suggests turning methane gas into electric power at the source. In fact, one large methane-fueled electric central station is now being built at Tavazzano.

In the meantime diligent prospecting for methane is being conducted not only in the Valley of the Po but also in the Marches, Calabria and Sicily. Two gravimetric and nine seismic teams are at present operating in the Valley of the Po for the State-controlled Agip Company which has delegated two more teams to prospect for it in other parts of the country. During 1950 a large number of wells were drilled, resulting in the discovery of new gas-beds at Caviaga, Ripalta and Cortemaggiore.

The present network of methane pipe lines in Italy totals 1300 kilometers with a total carrying capacity of 7 million cubic meters a day. In 1953 it will be increased to 200 kilometers and its carrying capacity will be raised to 13 million cubic meters a day.

Unfortunately, the prospecting for natural gas has not been accompained by any tangible results in the way of discovery of oil. The output of local petroleum remained during 1948, 1949 and 1950 at the level of about 9000 tons yearly. During the first 7 months of 1951 the output of petroleum reached 8055 tons which would mean some 14,000 tons for the whole of the year, a totaly inadequate figure.

Italian refineries of petroleum products are, on the other hand, doing very well. In 1950 they processed some four million tons of crude petroleum which is 30 percent more than in 1949 and 147 percent more than in 1938. No definite figures for 1951 are as yet available but the output of August, for instance, registered an increase of 32 percent in comparison with the same month of 1950.

During the last quarter of 1951 Italy was scheduled to import a total of 2,600,000 tons of coal of which 61 percent was to come from the U.S.A., 29 percent from Germany and the rest from other European countries. It is interesting to note that in 1950 American coal represented only 0.6 per cent of Italian coal imports. In 1949, however, this proportion was 41.7 percent and in 1948, 55.7 percent.

As regards the local production of coal, the bulk of it is represented by the brown coal of the Sulcis mines. Before the war 39,000 tons of it were produced monthly. In 1948 this figure rose to 72,000 tons and in 1949 to 84,500 tons. After a slight drop at the beginning of 1951 it began to climb again and reached 96,000 tons by August 1951.

Underground Gasification

Commenting on the recent International Conference on Coal Gasification, held in Birmingham, Alabama, and the symposium on coal gasification subsequently held in New York in connection with the AIME meeting, Interior Secretary Oscar L. Chapman offered the following summary:

1. The growing demand for gas, gasoline and chemicals has called widespread attention to the approaching need to employ coal as the raw material for these products.
2. Vast resources of low-rank coals and lignites, which cannot be exploited economically by standard techniques, are available for direct gasification.
3. Experiments with undergound gasification of coal in the bed have been carried out in Belgium, French Morocco, Italy, the United Kingdom and the United States. Also, large-scale model experiments using oxygen and steam have been conducted in Belgium.
4. A program of further systematic experimentation includes (a) employment of the perculation system involving electrical, hydraulic and pneumatic methods for connecting the vertical boreholes, thus avoiding the construction of underground tunnels; (b) the stream method in which preheated air is blown at high velocity through a prepared passage; and (c) a process using parallel passages opened along the pitch of the bed with unidirectional flow of oxygen and steam.
5. These systems are adaptable to a wide range of geological conditions, and their common aim is to produce gas at low cost with either air or oxygen, depending on the type of gas required.
6. Successful development of these processes may eventually reduce underground work, increase productivity, and open to economic access sources of energy previously unexploitable.
7. The consensus of the First International Conference on Underground Gasification was that public authorities and private enterprise should be encouraged to support the research program by all available means and to carry it out with as little delay as possible.
8. The cooperation which has long been developing among the several research centers and which finally brought about this first conference should be continued and a second conference held abroad within two years.

Facts and Figures

The bituminous coal industry in this country currently produces coal at the rate of approximately 4000 tons per minute.

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There are 298 privately owned Class A and Class B electric utility companies in the United States, according to the Federal Power Commission.

•

A large part of the city of Reykjavik, Iceland, is said to be heated by hot water derived from underground springs at temperature close to boiling.

•

Proved reserves of liquid petroleum in the United States reached 32.2 billion barrels at the end of 1951 which was an increase of 2.7 billion barrels during the year.

•

TVA will nearly double its installed capacity when its five new steam plants are completed, by which time about half its capacity will be steam, in contrast to its being predominantly hydro a few years ago.

•

To date approximately six billion dollars has been expended on atomic energy in this country, of which slightly more than half represents plants and equipment.

•

The Bureau of Mines reports that in three Oklahoma counties partly depleted oil fields have been made to yield 33 million gallons of oil by pumping water underground to provide the necessary pressure to get out the remaining oil. Water flooding was first employed for this purpose in 1931.

•

Electric utilities in the United States burned in excess of 105 million tons of coal during 1951, which was approximately 15 per cent above that burned in 1950. During the same period fuel oil dropped off 15.7 per cent and natural gas consumption increased 21.3 per cent. The net average coal rate was 1.14 lb per kwhr.

•

A new technique in underground gasification of coal was demonstrated during the recent "International Conference on Underground Gasification of Coal" at Gorgas, Alabama. This involves the passage of an electric current between two electrodes inserted in the coal seam to raise the temperature to the combustion point. It is known as the "electro-linking method of underground ignition."

•

The U. S. Chamber of Commerce points out that the foreign aid program for the next fiscal year contemplates the financing of a gigantic waterways system in France, one feature of which is a 354-mile seaway from the Mediterranean to Lake Geneva, 1230 ft above sea level, which would necessitate a series of locks.

Concentrating Films: Their Role in Boiler Scale and Corrosion Problems*

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The concept that a film of a very highly concentrated solution tends to form on steam generating surfaces and may cause scale formation is developed in this paper, which is slightly abridged. Characteristic effects of concentrating films and related deposition problems are discussed.

HOW and why do highly concentrated films develop on steaming surfaces? The answer can be made clear with the help of a few simple drawings.

Picture a large beaker being heated in a thermostatically-controlled oven which is vented freely to atmosphere (Fig. 1). Suppose the beaker contains 10 liters of water and 1 gram of sodium hydroxide—a 100 ppm solution. Such a solution can be concentrated indefinitely without throwing down precipitated material. And almost all boiler waters contain a certain amount of sodium hydroxide, often in concentrations of about 100 ppm.

If the thermostat of Fig. 1-A is set to hold temperature constant at 212 F., the solution will come up to this temperature but no appreciable evaporation will occur at atmospheric pressure. Of course, there will be some trivial evaporation until the gas space in the oven is filled with water vapor at atmospheric pressure, but the volume of the solution and its concentration will remain substantially unchanged.

Evaporation becomes significant if the thermostat is set higher than the boiling point of a 100 ppm sodium hydroxide solution, which is substantially that of pure water at the prevailing pressure. With the thermostat set at 214 F (Fig. 1-B), evaporation continues so long as the boiling temperature of the solution is less than 214 F. Decrease in liquid volume is accompanied by an increase in sodium hydroxide concentration which causes the boiling temperature to rise. Evaporation stops, and a new state of non-boiling equilbrium exists, when the solution and its surrounding vapor come to the same temperature (214 F). In reaching this equilibrium, the original volume of 10 liters will shrink to about 19 ml giving a sodium hydroxide concentration of about 52,690 ppm. (5 per cent by weight). Both the liquid and water vapor will be superheated 2 deg F above the saturation temperature of steam at 14.7 psia.

Setting the thermostat 3 deg F higher still (Fig 1-C) causes evaporation to resume and continue until the boiling temperature of the solution reaches 217 F. Non-boiling equilibrium will again result when the solution volume is reduced to about 9 ml, and the sodium hydroxide concentration is about 110,900 ppm (10 per cent by weight). Liquid and water vapor will be superheated 5 deg F above saturation temperature of steam at atmospheric pressure.

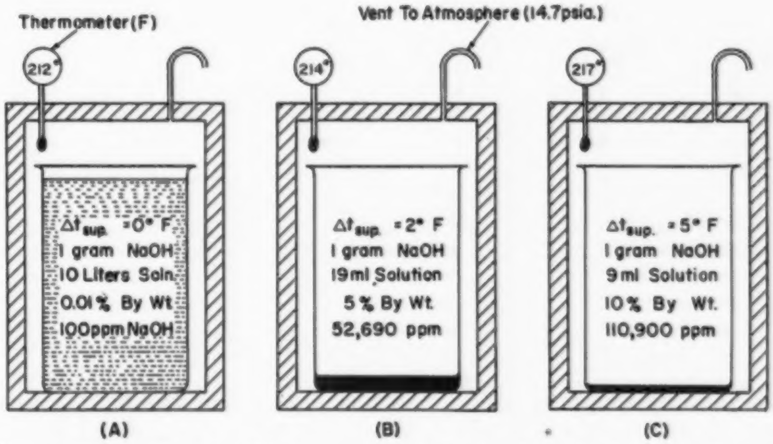


Fig. 1—Non-boiling equilibrium conditions of sodium hydroxide solution in a thermostatically-controlled oven

Fig. 1 illustrates only three of an infinite number of possible temperature-concentration equilibria. For any given temperature elevation, there is a corresponding non-boiling equilibrium concentration of sodium hydroxide. This is shown in Fig. 2. The difference between the temperature of the solution and the temperature of saturated steam at the pressure in question determines the maximum concentration which can be reached by process of evaporation. This temperature-concentration relationship is substantially independent of pressure.

Now, how can high concentrations of

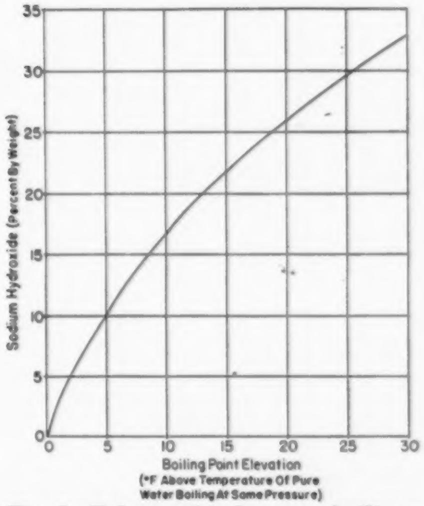


Fig. 2—Relationship between boiling-point elevation and sodium hydroxide concentration

sodium hydroxide be produced in a boiler, assuming non-turbulent conditions on steaming surfaces? Fig. 3 pictures a boiler tube and the three stages of temperature-concentration equilibrium shown in Fig. 1. Assume this to be a 1400-psia boiler tube uniformly heated at the rate of 25,000 Btu per hr per sq ft. Let the boiler water contain 100 ppm of sodium hydroxide but no other dissolved substance. Since heat is flowing into the tube, there must be some temperature drop across the tube wall and the metal-water interface. Accepted methods for calculating heat transfer under these conditions indicate temperature drops of about 24 deg F across the metal and about 5 deg F across the liquid film. Toward the center of the tube (region A), boiler water is at saturation temperature (587 F). But the thin film of liquid directly in contact with the metal (region C) must always be trying to approach that of the inner tube surface, i.e., it must tend to become superheated 5 deg F above saturated steam temperature.

As the temperature of film "C" rises above saturation, water evaporates there

* Presented at the Twelfth Annual Water Conference of the Engineers' Society of Western Pennsylvania. The complete papers and discussion are published in the Proceedings of the Conference which may be secured for $7.50 from the Engineers' Society of Western Pennsylvania with headquarters at the Hotel William Penn, Pittsburgh, Pa. A brief abstract of this paper appeared in the Water Conference report in the November 1951 issue of COMBUSTION, pp. 49–52.

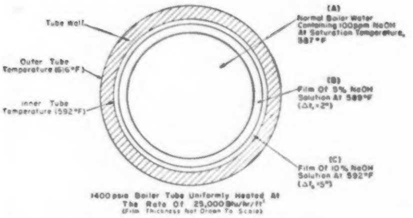


Fig. 3—Diagram of concentrating film in an actual boiler tube

with a corresponding increase in sodium hydroxide concentration. Evaporation continues until a 10 per cent solution is reached, for at this concentration the boiling temperature of the liquid equals that of the inner tube surface (5 deg F above saturation). Then a state of non-boiling equilibrium prevails, just as it did in Fig. 1-C. Under these conditions, therefore, the inner tube surface might be expected to be contacted by a 10 per cent caustic solution superheated to the extent of about 5 deg F. At any intermediate region between the metal and the boiler water proper, superheat and degree of concentration will be less. For example, equilibrium in the 2 deg F superheat zone (B) would correspond to a sodium hydroxide concentration of about 5 per cent.

Temperature gradient across the liquid film is believed to be continuous, and not stepwise as indicated in Fig. 3. Fig. 4 illustrates this by showing a section of the same tube cut longitudinally. Drawn to the left-hand (arithmetic) scale, the temperature curve represents a 24 deg F drop across the metal, and a 5 deg F drop across the liquid film. Each point on the temperature curve within the liquid film indicates the equilibrium liquid temperature at a given distance from the tube. But for each temperature so indicated, there is a corresponding equilibrium concentration of sodium hydroxide at that same distance into the liquid as shown on the right-hand (logarithmic) scale. Notice that while the temperature drop across the liquid film is only a few degrees, the concentration gradient is on the order of 100,000 ppm. Although the horizontal scale of distance from the tube is arbitrary, it is the same for both the temperature and concentration curves.

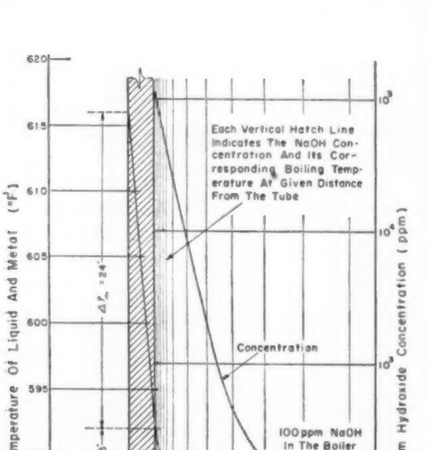


Fig. 4—Film concentration at any given distance from the tube as determined by the film temperature at that point

In any steaming boiler tube, transfer of heat establishes a temperature gradient across the film of liquid in contact with metal. This temperature gradient determines the total concentration of dissolved material that can accumulate in the film. The initial composition of the boiler water will naturally influence the final composition of the film solution, as will the precipitation of salts while evaporation is in progress. But for a given temperature gradient, the total amount of dissolved material remaining in the film, when non-boiling equilibrium is attained, will be about the same regardless of the initial composition of the boiler water. For example, in Fig. 3, film "C" would tend to develop the same equilibrium concentration (10 per cent NaOH), whether the initial boiler water contains 10, 1000, or 10,000 ppm of sodium hydroxide.

Up to this point two ideas have been developed: (1) a film of very highly-concentrated solution tends to develop on steam-generating surfaces, and (2) this "concentrating film" is the result of heat transfer from metal to a boiling liquid that contains dissolved material.

Mechanism of Steam Generation

Transfer of heat from metal to boiling liquid is the driving force that generates steam. The greater the rate of heat transfer, the greater will be the temperature drop across the liquid heat-transfer film. Since film temperatures and equilibrium film concentrations are related to each other, rate of heat transfer is an important factor in concentrating film phenomena and associated boiler-scale and corrosion problems.

Fig. 5 depicts several variations in the process of heat transfer from metal to liquid under non-boiling and boiling conditions. No boiling occurs at lower rates of heat input. Heat passes directly from metal to liquid, causing the liquid to be superheated in proportion to the rate of heat input and proximity to the metal. Nucleate boiling starts when heat transfer is great enough to form small bubbles at the metal surface. Steam in these bubbles is superheated slightly, since they form in contact with metal whose temperature is necessarily higher than that of the bulk of the water. In moving away from the metal, these tiny bubbles pass through a region of decreasing superheat and therefore tend to collapse by losing heat to the surrounding liquid. While some of these bubbles may coalesce into larger ones, they are too small and too few to survive; all condense before reaching the boiler water at saturation temperature.

Ebullition, i.e., actual steaming, starts when the bubbles are large enough and numerous enough to persist as a stable phase when they leave the region of superheated liquid. There may be some shrinkage in volume as bubbles pass through the zone of decreasing temperature. But if some steam remains when saturation temperature is reached, ebullition proceeds.

Increasing heat input causes more and more surface to be covered by bubbles, eventually producing a continuous blanket of superheated steam over the metal. In this case, heat passes first from metal to superheated steam, and then from superheated steam to superheated liquid. Film boiling occurs with evaporation taking place at the steam-water interface.

So long as heat flows from metal to liquid, there is a temperature gradient between the metal and the liquid at saturation temperature. If evaporation occurs within the film of liquid at elevated temperature, solids dissolved in the liquid will tend to concentrate until conditions of non-boiling equilibrium are satisfied, giving rise to the so-called "concentrating films."

Mechanism of Scale Formation

Fig. 6 shows four instants in the life of a steam bubble. First a tiny nucleus

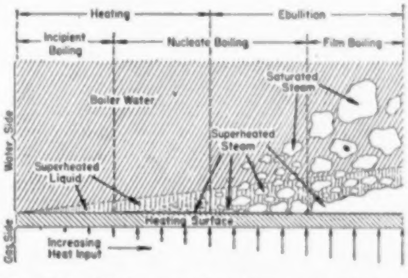


Fig. 5—The mechanism of steam generation

of steam forms at some favored point (Fig. 6-A). While the bubble is growing, evaporation occurs around a ring where the bubble joins the metal. Impurities in the water thus evaporated tend to concentrate in the ring. When saturation is reached with respect to some constituent in the water, precipitation results (Fig. 6-B). The process continues, leaving a film of highly concentrated brine or a crust of precipitated salts (Fig. 6-C). If the boiler water contains dissolved matter, a concentrating film is created under every steam bubble. Suspended or precipitated solids may be associated with the concentrating film.

Fresh boiler water flushes over the surface after each bubble becomes detached, tending to remove the concentrating film (Fig. 6-D). The net effect is a resultant of two opposing tendencies: concentration and rinsing. If rinsing is adequate, precipitated salts are dissolved away and the concentrating films are diluted as fast as they can develop in the course of bubble formation. On the other hand, if film concentrations build up more rapidly than they can be diminished by rinsing, continued repetition of the bubble-formation process will

result in scale accumulation or other adverse effects.

The character of the final solution attained on a steaming surface, and consequently the tendency toward scale deposition, depends upon three things: the relative amounts and types of impurities in the boiler water, the rate of heat transfer, and the vigor with which normal boiler water flushes the surface. Deposition can be minimized (1) by reducing the heat input so that lower concentrations will obtain in the concentrating films, (2) by increasing liquid velocity and turbulence so the concentrating films will be dissipated more rapidly, (3) by modifying boiler-water compositions to exclude those compounds that tend to crystallize or produce adherent residues under

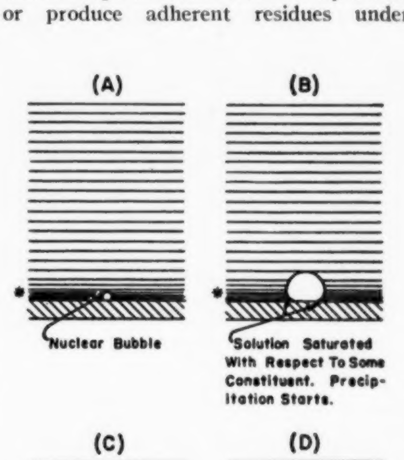


Fig. 6—The mechanism of scale formation

concentrating film conditions, (4) by adding special chemicals to disperse suspended solids in the boiler water and render them less resistant to rinsing, and (5) by reducing the total amount of dissolved and suspended matter in the boiler water.

Characteristic Effects of Concentrating Films

As mentioned earlier, evaporation continues at the metal-water interface until the boiling temperature of the concentrating film approximates that of the metal surface. If rinsing is too slow with respect to the rate of bubble formation, and if non-boiling equilibrium does not occur before saturation is reached for some constituent in the boiler water, that constituent will commence to precipitate as a deposit on the metal. All of the boiler-water components which might precipitate in this way may be thrown out of solution before the concentrating film

comes to non-boiling equilibrium. But if some caustic alkalinity remains in the concentrating film after substantially all of the dissolved salts are precipitated, caustic may concentrate to a high degree before non-boiling equilibrium is reached.

Caustic concentrations as low as 5 per cent may be aggressive to boiler steel. At this and higher caustic concentrations the protective oxide coating over the metal tends to dissolve. Metal thus exposed immediately reacts with water, attempting to form a new protective film of iron oxide. But when the caustic concentration remains high enough to prevent formation of an oxide film, reaction between the metal and the boiler water continues, and caustic corrosion occurs. Hydrogen produced as a product of this reaction may enter the metal and make it brittle.

Of course, a continuous layer of mineral salts precipitated from the boiler water may protect the metal against attack by caustic in the concentrating film. The chances for caustic corrosion (and hydrogen embrittlement) are therefore diminished by the presence of dissolved boiler-water salts which can precipitate in the form of a continuous protective barrier over the metal, although failure due or overheating may result instead.

"Hide out" of boiler-water phosphate, in the author's opinion, can be easily explained now. This constituent (Na_3PO_4) is less soluble than some of the other dissolved substances normally present in boiler water and, is one of the first salts to precipitate under severe concentrating-film conditions. When boiler load is reduced and the steaming surfaces are more accessible to rinsing by normal boiler water, the "hidden" phosphate is believed to go back into solution automatically. In extreme cases of phosphate "hide out" accompanied by high film concentrations of caustic, metal attack may occur and produce sodium ferrous phosphate as the corrosion product.

Some boiler-water components may decompose in the concentrating films. For example, hydrogen sulfide odors in a plant whose boilers are treated with sulfite may very definitely indicate "hot spots" where sulfite is breaking down. Organic treating chemicals or natural organic contaminants in the feedwater may sometimes decompose in concentrating films, producing carbonaceous residues which interfere with rinsing and thereby promote even higher film concentrations. Copper ions in boiler water may be reduced to metallic copper by hydrogen liberated in the course of caustic corrosion, thus accounting for large percentage of copper in deposits associated with caustic attack.

Certain studies have indicated that the amount of volatile silica in steam is proportional to silica concentration in the boiler water, the proportionality constant ranging from substantially zero (at pressures of 600 psig and less) to about 0.033 (at pressures around 2200 psig). Steam from some boilers seems to contain more volatile silica than predicted on the basis of operating pressure and boiler-water silica concentration. This situation may be simply due to the fact that silica

concentrations are considerably higher in the concentrating films than in the boiler water proper.

Problems Associated With Degree of Film Concentration

"Degree of film concentration" may be defined as ratio of steaming rate to rinsing rate on the steam-generating surface. It will increase with higher rates of steam generation but decrease with more efficient rinsing.

In Fig. 7, a dotted line is drawn to represent schematically the behavior of sodium hydroxide under conditions of increasing evaporation in the concentrating film. Being extremely soluble, sodium hydroxide does not precipitate; it increases directly in proportion to the degree of film concentration.

Most dissolved salts behave quite differently from sodium hydroxide. Boiler water containing calcium and carbonate ions cannot be concentrated very many times before it commences to precipitate calcium-carbonate scale, this being the least soluble calcium-scale material naturally present in boiler water.

Calcium sulfate scale requires a higher

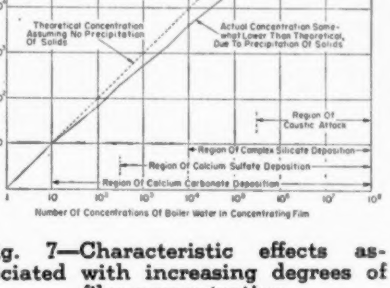


Fig. 7—Characteristic effects associated with increasing degrees of film concentration

degree of film concentration than that necessary to throw down calcium carbonate, since calcium sulfate is the more soluble of the two. Whether calcium carbonate or calcium sulfate, or a mixture of both, is obtained naturally depends on the concentrations of carbonate and sulfate ions in the boiler water. Fig. 7 attempts merely to illustrate the most common, or most probable, sequence of events with respect to increasing degree of film concentration. The representations are naturally quite arbitrary and present only a general and limited pattern of what happens in any actual boiler.

Formation of scale removes dissolved material from solution. In contrast to the dotted line, the solid line in Fig. 7 attempts to show that dissolved solids in the concentrating film increase to a lesser extent, for the same number of concentrations, while scale is precipitating. But when a point is reached where hardly anything but sodium hydroxide remains in solution, the concentration of this constituent increases in direct proportion to the degree of concentration in the film. It should be remembered, of course, that in

order to satisfy the final equilibrium determined by temperature gradient in the film, a greater or lesser number of concentrations may be required, depending upon the original composition of the water.

Formation of Complex Silicates

Complex silicates form under conditions of exceedingly high film concentrations. Typical complex silicates frequently found in boiler deposits are analcite ($Na_2O.Al_2O_3.4SiO_2.2H_2O$), acmite ($Na_2O.Fe_2O_3.4SiO_2$), noselite [$3(Na_2O.Al_2O_3.2SiO_2).2Na_2SO_4$], and sodalite [$3(Na_2O.Al_2O_3.2SiO_2).2NaCl$]. As a general rule, presence of any of these materials in a boiler deposit indicates localized excessive heat input or some interference with the normal rinsing process.

Salts such as sodium phosphate and sodium sulfate are ordinarily considered to be quite soluble in water, but even these may be thrown down as scale if the degree of film concentration is high enough. Water-soluble deposits generally indicate a degree of film concentration appreciably higher than that required to form complex silicates. Their presence can be taken as almost conclusive evidence that boiler water has been evaporated substantially to dryness in the concentrating film.

If the boiler water contains sodium hydroxide but no dissolved salts that can precipitate as a protective layer over the metal, this alkali may concentrate sufficiently to produce caustic corrosion and, possibly hydrogen embrittlement. Acmite (sodium iron silicate) may be formed as a result of caustic corrosion in the presence of boiler-water silica. When the boiler contains no dissolved material of any kind, exceedingly high rates of heat transfer may result in direct oxidation of the metal by superheated steam. In boiler tubes, this type of attack seems to occur only under conditions of film boiling.

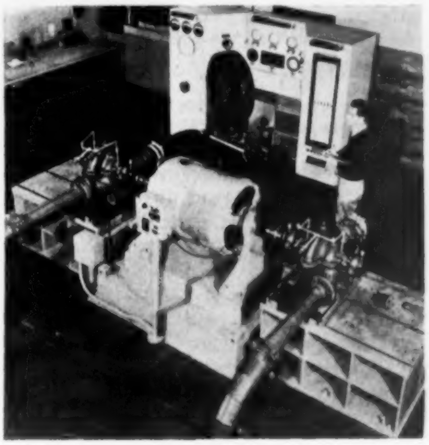
Concentrating Film Under Normal Heat-Flow Conditions

Thus far the emphasis has been on heat-transfer rate. However, the concentrating film may become troublesome even under normal heat-flow conditions. Anything that impedes rinsing is detrimental. Water-permeable deposits of any kind resist rinsing, and it is easy for boiler water to concentrate within the pores of such a deposit. For example, a boiler may remain quite clean under ordinary operating conditions. But suppose a small amount of oil contamination turns up sometime and causes a thin layer of oil-bound sludge to stick to certain steaming surfaces. Evaporation of boiler water within the pores of this adherent sludge might lead to complex silicate scale or even caustic attack of the metal. Similar effects might be produced by dissolved iron in the feedwater or the presence of any other binding substance that can form porous deposits. Failure through overheating or corrosion might thus occur at relatively conservative rates of heat input and in spite of excellent control over boiler-water chemical concentrations in general.

New Centrifugal Pump Test Stand

De Laval Steam Turbine Co., Trenton, according to Paul Nurko, test superintendent, has recently completed a series of newly-designed centrifugal pump testing stations which have greatly reduced overall test costs. These stations are engineered to give a complete reproduction of performance for pumps of all sizes and ratings. Although primarily designed for production testing, they have also proved valuable in research and development. Analysis of test data assembled over the first twelve months of operation has shown a direct reduction in testing time and a saving in man-hours that has effectively cut testing costs to 25 per cent of the previous established cost.

These test stands are permanent installations consisting of a double-ended, electric dynamometer mounted on an automatic lift located between two pre-aligned pump bedplates. The lift is powered by an electric motor operating through a self-locking gear train and is controlled by push buttons so placed that the test erector can readily secure proper height alignment within 0.22 in. One of the stations is capable of testing pumps up to 6-in. diameter discharge and requires the dynamometer to be set at various heights for the various size units. Signal lights and safety controls are built in for the dynamometer lift.



The test engineer operates the unit and conducts the test from a control desk and panel

Pump Alignment Features

The test erector has no need for a variety of tools. Pumps of one rotation are coupled to one end of the dynamometer shaft while those of opposite rotation are coupled to the opposite end. The dynamometer has sliding type couplings on which coupling bolts are permanently mounted. The pumps are automatically aligned laterally when set on doweled pads which have special clamping and alignment fixtures that reduce aligning time to a matter of minutes. An electrically operated one-ton crane simplifies pump handling.

(Continued on page 66)

Permanent Venturi Banks

The test station features a system of piping which simulates actual field installation. Pump suction piping includes a movable manifold deeply submerged in a swirl or vortex free pool of water. The interconnected reservoirs of water have a total capacity of 400,000 gallons. Special eccentric pipe reducers provide means of piping pump suction to the manifold and quick connecting adapters are used for piping connections. The water is discharged through a flexible hose that empties into a pipe system below the operating level.

Water is then metered through a bank of calibrated venturis, shown in the background, that can be operated singly or in parallel. The system head is low and by use of a motor-operated valve, additional friction is created so that pumps are tested over a wide range of heads. The pipe system requires no priming and is free of air locks. Suction lifts are applied to the pump for the control desk.

Test Panel and Instrumentation

The test engineer operates the unit and conducts tests from a control desk and control panel which contains highly sensitive instruments. The venturi manometers are calibrated to read directly in gallons per minute with the graduations so arranged that capacities may be read closer than is possible with a rule. Given flows are then set by the operator with a button-controlled valve. A gage tester is mounted in the control cabinet so that calibrations can be obtained in a matter of seconds.

A standard springless scale on a fixed motor arm indicates the motor torque. This method has proved to be most reliable and trouble free for indicating the absolute value of the torque. By use of selsyns, the torque may be read to the tenth of a pound on one of the control panel dials. For the test engineer's use, a field and armature ammeter and a voltmeter are included.

The dynamometer speed is controlled from the desk by use of two field rheostats. With the vernier rheostat, the speed may be adjusted to the exact value for which the pump is designed to operate. Voltage fluctuations are practically negligible with the use of a voltage regulator.

The speeds are set approximately with a synchronous electric tachometer, and held accurately by means of a stroboscopic light. Through a specially colored, marked transparent disk revolving in synchronism with the pump shaft the speed is held constant. For calibration of the electric tachometer, the average speed may be measured within one revolution per minute by using an automatic synchronous counter. All speed instruments are mounted in the control panel beneath the pressure gages. Moreover, the arrangement of instruments in the control panel provides the engineer with a clear vision in the observation and recording of the test data.

Such shop test installations, simulating actual industrial service, are intended to insure performance regardless of the rating of the pump.

ASME Meets on Pacific Coast

THE Spring Meeting of the American Society of Mechanical Engineers was held in Seattle, Washington, March 24–26, with a varied program that also touched upon developments and problems of the Pacific Coast and Northwest. Brief abstracts of a few of the fuels and power papers follow.

Design for Reduced Maintenance

In a paper dealing with the effect of maintenance on design, **B. C. Mallory** and **F. W. Argue,** both of Stone & Webster Engineering Corporation, cited Federal Power Commission data to show that it costs nearly twice as much to keep capacity in service in the average central station as it did ten years ago, even though a third of the capacity is new. While there are a number of factors affecting maintenance costs, the authors confined the paper to the provision of facilities that permit rapid overhaul and thereby minimize maintenance expense.

It has been common practice to provide space for dismantling main turbine-generators and boiler feed pumps, as well as for cleaning and retubing condensers, but with the increased complication of modern steam power plants there are many other items for which the designer should make provision. These were illustrated by views and layouts taken from two late plants—one a central station and the other an industrial plant. They included:

1. Installation of air preheaters, ducts, fans and fly-ash collectors at ground level outdoors.
2. Suitable protection for workmen against inclement weather when working on outdoor equipment.
3. Arrangement by which traveling screens and circulating water pumps may be lifted by a mobile crane.
4. Removable checker plates and open wells in the turbine room through which the main crane may be used.
5. Access roads over which trucks may travel to deliver supplies at the basement level.
6. Conveniently located and accessible lockers for tools, brooms, etc.
7. Provision of a portable electric welding machine with plug-in outlets at suitable points in the station to avoid excessively long leads.
8. Adequate centralized space for storage of miscellaneous lubricants to avoid oil and grease storage in various locations which is not conductive to good housekeeping or efficient maintenance.
9. An outdoor shed is often desirable for storage of refractories, insulation and other materials for which it is uneconomical to provide live and heated storage space.

Canadian Oil for Pacific Coast States

California oil reserves are considered inadequate to supply steadily mounting Pacific Coast demands, which have already outstripped present production in the California oil fields. On the other hand, oil discoveries in the Province of Alberta, Canada, have continued steadily over the past five years until it is now necessary to find new markets if the present supply is to be fully utilized and further exploration not be retarded.

According to **D. L. Roberts,** vice-president of Canadian Bechtel, Ltd., Canadian oil is to be brought through passes in the mountains by a 700-mile pipe line from the vicinity of Edmonton to Vancouver, British Columbia. This line is scheduled to be completed late in 1953 and will be capable, initially, of delivering 75,000 bbl per day.

Although the anticipated demand in British Columbia by 1954 is only 37,500 bbl per day, there is strong probability that the throughput of the line will be stepped up substantially soon after its completion in order to help meet the situation in California, Washington and Oregon; although it will be necessary to increase greatly the refining capacity in the two last-mentioned states.

Mr. Roberts further emphasized that the bringing of crude oil to British Columbia and the Pacific Northwest by a protected inland medium is vital to the defense policies of both Canada and the United States, as now practically all oil and refined products must be shipped in by tanker. For this reason defense authorities have made the necessary tonnages of steel pipe available.

P. G. & E. 34-In. Gas Line

This gas pipe line, described in a paper by Messrs. **J.J. Pugh, R. L. Hamilton** and **R. Finnie,** and recently completed by the Pacific Gas and Electric Company, delivers 400 million cubic feet of natural gas daily from feeder lines in Western Texas and New Mexico to the southern shore of San Francisco Bay. It is 502 miles long, 34 in. diameter and has a tapered wall thickness. There are three gas-engine-driven reciprocating compressor plants, one of 15,000 bhp at Topock, another of 17,500 bhp at Hinkley and a third of 12,320 at Kettleman.

Employment of a tapering wall thickness ranging from $^1/_2$ to $^5/_{16}$ in., to take advantage of the decline in pressure gradient, effected a saving of approximately four million dollars. Steel plate was used and the longitudinal joints were welded by the automatic shield-arc process, then expanded hydraulically in dies to render them perfectly round.

Turbine-Generators for Industrial Plants

Types of industrial plant turbines, features of their design, various applications and systems of control, were discussed at some length in a paper by **S. D. Fulton** of the Westinghouse Electric Corporation.

Such units, he explained, are usually of the impulse type which lends itself to relatively small volumetric steam flows with good efficiency; because with partial admission stages, favorable disk diameters and blade lengths can be employed. In the larger sizes the impulse-reaction type is frequently used.

Eight basic types of turbines were listed and illustrated and their functions summarized. These were (1) straight condensing; (2) condensing with automatic single extraction; (3) condensing with automatic double extraction; (4) straight noncondensing; (5) noncondensing with automatic single extraction; (6) noncondensing with automatic double extraction; (7) condensing with steam extraction or induction, according to whether there is an excess of steam at the process pressure or a deficiency of steam; and (8) mixed pressure, in which steam is inducted when the pressure in the turbine at the induction point is lower than that of steam in the line to which it is connected. Any one or more of these types can be employed to obtain the best balance between steam and electrical demands.

Nonautomatic extraction is now little used in industrial plants since the steam pressure is uncontrolled; hence it is not suitable for process; although nonautomatic extraction above the automatic extraction point may be used for feedwater heating.

With reference to selection of steam conditions, which is primarily an economic matter, Mr. Fulton stated that reliable industrial equipment for pressures up to 1250 psig and 900 F, even in small sizes, is now available. Temperatures at the turbine exhaust or extraction opening need not be a determining factor since a spray-type desuperheater or a thoroughfare desuperheating heater can reduce the temperature to near saturation. Furthermore, condensing processes can usually tolerate a considerable amount of superheat, since the condensing temperature is determined by the condensing pressure rather than the total temperature of the steam.

It is obvious that raising the initial pressure and temperature will permit generation of more by-product power; and less obvious, but equally true, is the fact that a noncondensing turbine will produce specific quantities of electric power and process steam with upwards of 5 per cent less throttle flow than a condensing-extraction turbine. Therefore, in specifying capacity of a turbine, care should be taken to avoid specifying excess extraction capacity as this will impair the turbine performance. When process steam pressures are close, it may be more economical to extract at the higher pressure and employ a reducing value for the lower pressure.

Wood-Waste-Fired Gas Turbine Unit

As part of a program directed toward the generation of power from waste wood, chiefly sawdust, at the Oregon Forest Products Laboratory, an experimental unit was constructed and has been in operation since November 1950. This, together with test results, was described in a paper by **G. H. Atherton** and **S. E. Corder** of the Laboratory staff.

This experimental installation consisted of an aircraft turbosupercharger set up as an open-cycle gas turbine, the combustion system of which consisted of an underfeed stoker supplied with undergrate air, overfire air jets and dilution air admit-

ted above the furnace. Gas temperature was regulated by varying the undergrate air supply to give an immediate change in the burning rate. Once this was accomplished, the fuel rate was increased or decreased to serve as the primary control of turbine inlet temperature.

Combustion efficiencies of 92.5 to 99 per cent were obtained with heat release rates up to 900,000 Btu per sq ft per hr and 190,000 Btu per cu ft per hr. The maximum static pressure loss through the furnace grate was 0.26 in. of water.

Gas Turbine Development

F. T. Hague of Westinghouse Electric Corporation reviewed the history of gas turbine development in both Europe and the United States beginning with three commercial installations in Switzerland in 1940 and 1941. These were a 2000-kw closed-cycle Escher Wyss unit in Zurich, a 4000-kw open-cycle Brown Boveri standby unit installed in an underground bomb-proof station in Necuhatel, and a 2000-hp gas-turbine locomotive on the Swiss Federal Railways.

The war held up further commercial installations for stationary plants, but predating these there was progress in the field of military aviation, contracts for jet-propelled gas-turbine-power aircraft for the German government having been let in 1938 and a jet-propelled plane was tested in England in 1939. From 1943 on, jet-propelled planes began to assume importance in the United States.

However, commercial gas-turbine development in England is currently being carried on by a group of firms, aside from aviation activity, one basic premise of the British objective being to sell its technology in gas turbines as an export in the form of licenses.

With the termination of war restrictions interest in the United States was stimulated by what was going on abroad and several prototype gas-turbine power plants of 500 to 5000 hp have been built here.

In Switzerland Brown Boveri has 17 sets built or building and has put into operation throughout the world 14 gas-turbine units of 85,000 kw total rated capacity. These are open-cycle units employing compressor intercoolers and regenerators. These are designed for 1112 F top temperature which means much heavier units than those of the 1400-F standards as favored in the United States. However, the lower temperature level permits use of conventional turbine steels instead of costly high-temperature alloys.

Escher Wyss, following the 2000-kw closed-cycle demonstration unit, built one of 12,500 kw which is now in operation at the St. Denis Station in Paris. An essentially duplicate machine is now being installed at Dundee, Scotland, by their licensee, John Brown Ltd. of Glasgow. Also, a 700-kw waste-heat closed-cycle unit is being built for a gas works at Coventry, England.

Sulzer Bros. built a 20,000-kw semi-closed-cycle 1250-F gas-turbine plant which went into service in 1950 at Weinfelden.

The nonaviation gas-turbine situation in England is strongly supported by government funds through contracts with private firms. In the commercial field at least nine units ranging from 750 to 20,000 kw are now under construction by four British firms.

In the United States, in the power generation field, General Electric Company is reported to have two 3500-kw units in operation and several under construction. Westinghouse has one 5000-kw and one 15,000-kw unit on order for installation in 1952 and 1953. In addition there is the development work being carried on at the Locomotive Test Plant at Dunkirk, N. Y.

Commenting on the general economic situation, Mr. Hague observed:

"The prospect of gas-turbine applications and the pattern of development being followed is basically similar but differs in essential respects in Switzerland, England and United States. The gas turbine in its present stage of development is an economic and practical reality in all parts of the world for certain types of applications. These fields of application exist when either the cost of fuel, plant load factor or plant first cost is sufficiently low or where the advantages of small size, portability, or absence of water requirements can be evaluated. In the low cost liquid and gas fuel regions of the world the complete gas turbine plant out-evaluates the complete steam plant in sizes up to 15,000 kw and this dividing line may be doubled within the next few years, as attractive new forms of gas turbine plant now building are proved out in operation.

Business Notes

The Swartwout Company, Cleveland, has appointed the firm of Mercator de Mexico S.A. as its sales and engineering representative to handle its line of power-plant equipment in Mexico.

Baldwin-Hill Company, manufacturer of industrial mineral wool insulations, has appointed P. A. Bell as its New England district sales manager. He will operate, however, from the Company's sales office at 500 Fifth Avenue, New York.

Midwest Piping & Supply Company's eastern division has been moved to 50 Church Street, New York City, with L. C. Voyce as manager.

Green Fuel Economizer Company, Beacon, New York, has added the Aerodyne dust collectors to its line of products. Developed in Sweden before the war, this type of collector was first introduced into the United States in 1949 and has already been installed in a number of well-known plants.

The C. O. Bartlett & Snow Company, Cleveland, is opening a Pittsburgh Office at 91 Central Square, Pittsburgh 28, where it will be represented by John M. Marston.

C. H. Wheeler Mfg. Co., Philadelphia, has named John M. Sperry sales manager of the Heating Pump Department of its Economy Pump Division.

Film-Rupture Mechanism Of Stress Corrosion

Stress-corrosion cracking, caused by the combined action of stress and corrosion, can be responsible for the spontaneous service failure of objects ranging from those of brass to those of stainless steel. A continuing investigation at the National Bureau of Standards, conducted by Hugh L. Logan, now provides new data on some of the mechanical and electrochemical phenomena involved.[1]

Corrosion is generally considered to be an electrochemical phenomenon, involving the flow of minute electrical currents between areas of different potential. When most metals are exposed to ordinary atmospheres, a thin oxide film is quickly formed that tends to protect the metal from further corrosion. According to the most generally accepted theory,[2] which the Bureau study tends to confirm, stress-corrosion cracking starts with a scratch or break in this protective film. When the protective film is broken through, the freshly exposed metal is more anodic (more negative) than the surrounding film-covered surface, and if moisture is present an electric current flows that causes the metal to be removed from the exposed area.

According to Mears, Brown, and Dix "if attack penetrates preferentially along a narrow path, it would appear axiomatic that a component of tensile stress normal to the path would create a stress concentration at the base of the localized corroded path. The deeper the attack and the smaller the radius at the base of the path, the greater would be the stress concentrations. Such a condition would act to pull the metal apart along these more or less continuous localized paths. At sufficient concentration of stress, the metal might start to tear apart by mechanical action . . . the tearing action described above would expose fresh metal, unprotected by films, to the action of the corrosion environment. Because this freshly exposed metal is more anodic, an increase in current flow from the base of the localized path to the unaffected surface would be expected, and hence there would be an acceleration of corrosion. Further corrosion would result in further tearing of the metal, and as a result increased rate of penetration would occur because of the mutual effect of the corrosion environment and the tensile stress."[2]

To get a better understanding of the forces at work in stress corrosion, the investigators measured electrochemical potentials of five alloys in normal film-covered and film-free conditions, both stressed and unstressed. Specimens were immersed in a suitable electrolyte, and potentials were determined using a calomel reference electrode of the saturated KCl type.

Studied were an aluminum alloy, a magnesium alloy, two brasses, a low-carbon steel and a stainless steel. Potentials were measured first for unstressed specimens having normal thin oxide films resulting from ordinary atmospheric exposure. Potentials were then measured for the same specimens after the filmed surfaces had been removed by abrasion with metallographic polishing paper. The

abrading was done in an inert-gas (argon) atmosphere in a dry box, and the potentials were measured without removing the abraded specimen from this atmosphere. Each metal studied was more cathodic (more positive) in the normal film-coated form than in the abraded form, by amounts ranging from approximately 0.12 volt to 0.76 volt.

The electrochemical solution potentials of the same alloys, in the normal film-covered conditions, were then measured with stress applied. It was postulated that, when tension is initially applied to a metal, small breaks develop in the protective film, giving corrosion a chance to get started before a fresh film can form. If the electrochemical potential of the unprotected area alone could be measured, it would presumably be roughly the same as that of a film-free surface. Measurement of change of potential with stress has been attempted before, but the attempts have generally been unsuccessful.

At the Bureau the measurement problem was solved by coating an entire notched specimen with a non-conducting waterproof lacquer, then using a razor blade to remove a narrow band of lacquer at the root of the notch. With specimens thus prepared, the only potential being measured was that of the narrow band of metal.

[1] For further technical details, see "Film-Rupture Mechanism of Stress Corrosion," by Hugh L. Logan, *J. Research NBS*, **48**, (Feb. 1952), RP 2291.

[2] Proposed by R. B. Mears, R. H. Brown and E. H. Dix, Jr., Symposium on Stress Corrosion Cracking of Metals, ASTM and AIME, 1944, p. 323.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Fluid Flow in Pipes

By Clifford McClain

For engineers or students this book is an ideal introduction or refresher covering the mechanics and dimensions of gas and liquid flow in pipes and ducts. The fundamental physical processes involved are explained in simple language, and the dimensions used in various systems of calculation are clarified.

The properties of fluids affecting flow are discussed with illustrations of the overall influence of each. Theory, measurement and dimensions of viscosity, with particular attention to relationships between various methods of measurement, are carefully explained for the beginner, while derivation calculations are included for those who wish to explore the subject more deeply. Friction and energy balance problems involving turbulence and streamline flow are solved with emphasis upon consistency in the evaluation of such factors as the Reynolds number. Empirical formulas used in flow calculations are presented with a discussion of the physical basis for such formulas.

Applications of the principles in the book to problems in piping and duct work are presented with calculations. Engineers and others who encounter only an occasional problem having to do with fluid flow, and whose knowledge of the subject may have become a little hazy, will find particular value in the straightforward tracing of consistent dimensional units through the calculations involved. The book fills a need for a treatment of the theory and practice of fluid flow in pipes from a dimensional viewpoint. It will not only enable the reader to gain a thorough understanding of basic principles but it will also help him to determine for himself whether he has expressed the terms of his calculations consistently.

The book contains 128 pages, 18 illustrations, 9 tables, is bound in maroon fabrikoid, and sells for $3.

Elevated-Temperature Properties of Stainless Steels

This 120-page 1952 report, prepared by Ward F. Simmons and Howard C. Cross of Battelle Memorial Institute and issued under the auspices of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals, is essentially a graphical summary of elevated-temperature data for the commercially produced stainless steels. Included are summary curves for tensile strength, 0.2 per cent offset yield strength, per cent elongation, per cent reduction of area, stresses for rupture in 100, 1000, 10,000 and 100,000 hr, and stress for creep rates 0.0001 and 0.00001 per cent per hr (1 per cent in 10,000 and 100,000 hr).

An Appendix contains the primary data from which the summary curves were drawn. The data sheets in the Appendix give the chemical composition, processing data, and other pertinent information about the steels included in this survey.

The following compositions are covered with charts and tables:

18 Cr—8 Ni	25 Cr—12 Ni
18 Cr—8 Ni Ti	25 Cr—20 Ni
18 Cr—8 Ni Cb	25 Cr—20 Ni Si
18 Cr—8 Ni Mo	15 Cr—35 Ni
18 Cr—8 Ni Mo Cb	

This collection of data resulted from the close cooperation of many leading organizations concerned with the production of stainless alloys, their fabrication into valves, flanges, fittings, piping, etc. and the users. It should be of widespread interest—especially to those establishing stress values and code requirements; the designer of equipment, particularly where elevated temperatures are involved; the metallurgist supervising production of steels or the construction and products

therefrom; and the technical people concerned with operating problems.

In order that the graphs and data would show up clearly and in appropriate size for ease of reading, the publication is issued in page size $8^1/_2 \times 11$ in. There are 120 pages and the book, bound in heavy paper cover, is priced at $4.

ASHVE Guide

The 1952 edition of The Heating, Ventilating and Air Conditioning Guide, published annually by The American Society of Heating and Ventilating Engineers, has just been issued. This is the 30th edition with a total of 1520 pages of which over 1000 pages contain technical data.

The chapter arrangement of the past two editions has been retained, under the familiar section titles: Fundamentals, Human Reactions, Heating and Cooling Loads, Combustion and Consumption of Fuels, Systems and Equipment, Special Systems and Instruments and Codes.

New codes and the latest editions of all codes pertinent to the field have been included. The section on water vapor and condensation in building construction has been rewritten and enlarged, particular attention having been given to the discussion of visible and concealed condensation and to methods of preventing moisture damage in buildings. A number of new materials are listed in the tables of conductivities and conductances.

The tables of unit conductances for thermal convection and methods for computing radiant heat exchange for various conditions have been brought into agreement with latest research results.

Average winter temperatures for October to May were obtained from the U. S. Weather Bureau and the Canadian Meteorological Service and are listed in the table of winter climatic conditions for 316 United States cities and 16 Canadian cities.

Design tables for heat gain through flat glass and glass block have been simplified, and others for rolled glass have been added.

The sections dealing with oil and gas fuels have been rewritten and expanded to include more information on properties and combustion data for present-day fuels. Boiler rating information has been brought up to date and a new abridged table showing current I-B-R boiler rating and sizing practice has been added.

The table showing recommended air conditions for manufacturing, storing and handling various types of products has been greatly enlarged, and many important factors affecting the processes involved have been listed with the various products.

The air filter section has been rewritten to provide more data on types of filters and dusts encountered. Information has been added describing the charged-media type of filter.

The section on the absorption system has been enlarged to include a diagram and description of the lithium bromide-water absorption system. Also, data have been added on application of fans for high temperature work. Nomenclature and designations for fans have been brought into accord with latest industry practice.

The volume is priced at $7.50.